Determinants of the Own-Race Bias and neural correlates of own- and other-race face processing

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1 Preface

Interacting with people from different ethnic backgrounds is becoming a ubiquitous element of everyday life for an increasing number of people. While this may be a necessary side effect of globalization and may help to overcome stereotypes and prejudices against people from other cultures or ethnicities, very basic problems pertaining to the perception and recognition of individuals from different ethnicities are often overlooked – sometimes with dramatic consequences for the individual (e.g. in the case of eyewitness accounts, Meissner & Brigham, 2001). Even though many people can relate to the phenomenon of the own-race bias from personal experience, its relevance and potential impact on personal interactions in cross-ethnic environments and societies are very often underestimated and easily forgotten.

The own-race bias describes the finding that people are generally better in recognizing faces from their own ethnicity as opposed to faces from another ethnicity. Over the course of the last 30 years, various theories have been put forward to account for this phenomenon. However, ethnicity not only affects the behavioral outcomes of perceptual processing, but also neural correlates of the processing of own- and other-race faces. The present thesis therefore aims at providing empirical evidence for the role and impact of various factors on the own-race bias and their effect on ERP-correlates of own- and other-race face processing.

However, I would not be able to actually provide this evidence without the support I received from so many people over the course of this PhD.

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Furthermore, I would like to thank all previous and present members of the department for the great team spirit and the fun I had working with you – you made this time an unforgettable and amazing experience.

Last but not least, my heartfelt gratitude goes out to my friends, siblings and parents. Thank you for always believing in me and for making me strive for more than what seems possible at first. I owe you much more than I can ever give back.

Introduction

1.1 The own-race bias in face perception

> *In the early hours of May 11, 1978, a white couple was kidnapped from a gas station in suburban Chicago and brutally murdered. The young couple, Larry Lionberg and Carol Schmal, had just become secretly engaged. Both were taken to an abandoned townhouse in the black community of East Chicago Heights, where police found their bodies at mid-morning on May 12. The Cook County Sheriff's Police took charge of the investigation and soon received an anonymous call claiming that the killers were among onlookers at the crime scene and that they drove "a red Toyota and an orange Chevy". Police officers were notified and approached the crowd, a moment at which two young black men "bolted" and, while looking over their shoulders, started walking toward a red Toyota. The two young men, Dennis Williams and Verneal Jimerson, were taken into custody and together with two of their friends, Kenneth Adams and Willie Rainge, accused of the murder. Even though one of the two available eyewitness accounts was insecure in regards to the ethnicity or gender of the suspects, three of the four men were identified as being involved in a commotion witnessed at the deserted townhouse and later crime scene. A second eyewitness account was obtained under dubious circumstances, again clearly framing the four men as suspects. In what became known as the case of the Ford Heights Four, the young men were indicted and convicted for double murder. Dennis Williams and Verneal Jimerson were sentenced to death, whereas Willie Rainge and Kenneth Adams were sentenced to prison terms for life and 75 years, respectively. In 1983, legal journalist Rob Warden exposed serious problems in the case, but it took another 14 years and the help of many activists to exonerate the four innocent men.* (Protess & Warden, 1998. *A Promise of Justice - the eighteen-year fight to save four innocent men*. Hyperion)

In cases like this one, even minor problems and lapses inherent to the perception and recognition of people from a variety of ethnicities may infer fatal consequences. One critical circumstance in the criminal case described above which led at least in

part to the conviction of the four men was identification by an eyewitness from another ethnicity than the suspects' own ethnicity. As research has been demonstrating, misidentifications are much more likely to happen in cross-ethnic circumstances, i.e. when the witness and the crime suspect belong to different ethnic groups. A so-called own-race bias in face recognition has been first described over four decades ago (Malpass & Kravitz, 1969) and to this day continues to attract scientific attention. In general, the own-race bias can be described as the finding of decreased recognition accuracy to faces from another ethnicity as compared to faces from the observer's own ethnicity. By contrast, and somewhat paradoxical, categorization of faces in regard to their ethnicity has been found to be faster and thus easier for other-race faces, a finding that has been confirmed in a number of experiments (for a review, see Meissner & Brigham, 2001).

Empirical research on these phenomena in face recognition has yielded evidence for a number of factors influencing the own-race bias. However, the precise underlying mechanisms are still under discussion and in need of further clarification.

Theoretical explanations of the own-race bias

Several theories have been put forward to account for the differences in own- and other-race face recognition, and even though a number of different explanations have been suggested, most of these theories can be subsumed in two broad groups, which will be discussed in some detail below. Whereas one group of theories suggests perceptual learning and lifetime expertise with own-race faces and a lack of perceptual expertise with other-race faces as the basis of the own-race bias, another group of theories assumes that socio-cognitive processes (such as "in-group/out-group" categorization or cognitive disregard) cause the own-race bias and stress the importance of the situational context on own- and other-race face recognition.

1.1.1 Expertise-based explanations of the own-race bias

From an expertise-based viewpoint, the own-race bias may be explained as a result of lifelong experience with faces of primarily one ethnicity, an effect that shapes an observer's representation in a way that is best suited to encode and represent faces from the observer's own ethnic group.

The probably most prominent expertise-based model of the own-race bias is the so-called multidimensional face space (MDFS) model developed by Valentine (Valentine, 1991). In this model faces of different individuals are coded as points in a

multidimensional space along different dimensions. It should be noted that Valentine did not specify which exact dimensions constitute the MDFS. However, experience accrued over the observer's lifetime serves to specify those dimensions that are best suited to optimally discriminate between individual faces. In line with findings of an interdependence of an observer's ethnicity and the characteristics used to differentiate between faces of different ethnicities (Blais, Jack, Scheepers, Fiset, & Caldara, 2008), it appears plausible that not all dimensions of the face space are equally suitable for discriminating between individual faces of different ethnicities. Within the scope of the MDFS account, two specific models were postulated. As detailed below, the norm-based and exemplar-based models differ in their predictions of the effect of several variables on recognition performance.

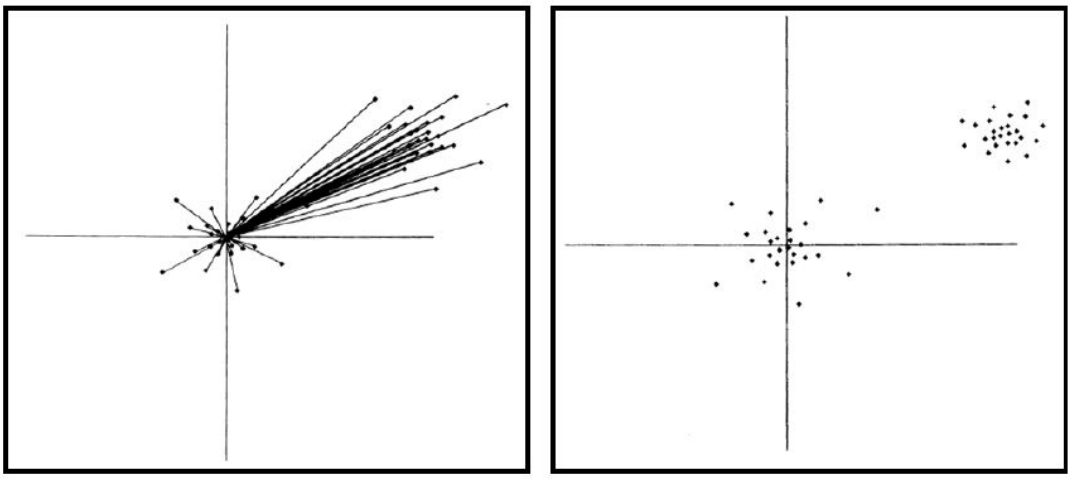

Figure 1: Multi-dimensional face space with the norm-based model (left) and exemplar-based model (right), illustrating the representation of own-race (centrally located) and other-race faces (decentrally located) in face space (from: Valentine & Endo, 1992, pp. 697 and 677)

The norm-based model (cf. Fig. 1) assumes that individual faces are stored in relation to a population norm or an abstracted prototype, with faces sharing greater similarity with the prototype located closer to the origin of the face space. Therefore, each face is assumed to be encoded as a vector from the origin of face space to the specific point that specifies the location of the face on the dimensions of face space. Consequently, faces that deviate from the norm are represented as farther away from the origin of the face space. On the contrary, the exemplar-based model (cf. Fig. 1) assumes that faces are stored as absolute representations instead of a relative function of the deviation of an individual face from an abstracted prototype. Importantly, in both models the similarity between two faces can be described as a monotonic function of the distance between their representations in face space.

However, whereas both models make similar predictions about the effect of distinctiveness on *face recognition* (with faster and more accurate responses to

distinct as compared to typical faces due to shorter vectors in the norm-based model and relatively lower exemplar density in the exemplar-based model), the norm- and exemplar-based model differ in their explanations of the effect of distinctiveness on *face classification* (with faster classification of typical as compared to distinct faces). Whereas the norm-based model explains this effect in terms of smaller deviation from a prototype and therefore shorter vector lengh, the exemplar-based model assumes that higher exemplar density results in an increased activation for typical faces and therefore faster classification.

Subsequent studies on effects of ethnicity compared diverging predictions of both models. The majority of these studies yielded empirical support for the validity of an exemplar-based model (Rhodes, Proffitt, Grady, & Sumich, 1998; Rhodes, Carey, Byatt, & Proffitt, 1998; Valentine & Endo, 1992), by assuming that representations for faces from another ethnic group are located in different regions in face space as compared to own-race faces. As described above, it is assumed that an observer's face space is the result of lifetime experience with individual faces which in turn shapes the dimensions of the MDFS to optimally discriminate between these faces. Since most people grow up in ethnically homogenous societies and therefore acquire only limited experiences with faces from ethnicities other than their own (Furl, Phillips, & O'Toole, 2002), the dimensions used to construct an observer's MDFS are suggested to be optimally suited for the discrimination of own-race faces at the cost of inferior coding and recognition of other-race faces. In line with the exemplar-based model, it is further assumed that other-race faces are more densely clustered (Byatt & Rhodes, 2004) and located towards the outer limits of an individual's face space, whereas the representations of own-race faces are spaced further apart, which in turn results in less misidentifications and higher recognition accuracy for the latter group of faces (Valentine & Endo, 1992).

This hypothesis of an expertise-based account of the own-race bias is supported by a multitude of empirical findings. First, it has been shown that expertise with own-race faces acquired over an observer's lifetime is correlated with an increasing own-race bias (Walker & Hewstone, 2006a). In addition, it has been found that differential recognition accuracies to own- and other-race faces occurred at the age of 7-10 years, but not in younger children (Chance, Turner, & Goldstein, 1982; Corenblum & Meissner, 2006; Pezdek, Blandon-Gitlin, & Moore, 2003; Walker & Hewstone, 2006a), analogous to a general increase in expertise to faces and an augmentation of discrimination performance from childhood to adulthood (Carey, 1992; Mondloch, Maurer, & Ahola, 2006). Thus, it has been suggested that the own-race bias increases with age (Chance et al., 1982; Walker & Hewstone, 2006a; but also see Pezdek et al., 2003; Corenblum & Meissner, 2006). In line with a perceptual

expertise account of the own-race bias, studies on the influence of contact with other-race individuals have demonstrated a reducing effect of contact on the own-race bias (Chiroro & Valentine, 1995; Hancock & Rhodes, 2008; Walker & Hewstone, 2006b), so that participants who had acquired expertise with other-race faces through intensive contact with individuals from another ethnicity exhibited lower own-race bias scores. These findings were additionally supported by studies, in which adoption of Asian infants and toddlers into Caucasian families either abolished (de Heering, de Liedekerke, Deboni, & Rossion, 2010) or even reversed the own-race bias (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). Furthermore, simulations demonstrated that an auto-associative network trained to individuate a majority and a minority race of faces reproduces an own-race bias in recognition performance that is comparable to the own-race bias in humans (Furl et al., 2002; O'Toole, Deffenbacher, Abdi, & Bartlett, 1991), with higher recognition accuracy to faces that belong to an experimentally induced majority race of face, while simultaneously exhibiting inferior recognition performance to faces from a minority race. In line with this, a recent examination which aimed at the construction of the theoretically predefined MDFS (Catz, Kampf, Nachson, & Babkoff, 2009) demonstrated that the facial dimensions rated to be important for recognition by a large sample of participants indeed reflected the psychological experience in face recognition and hence validated the theoretical MDFS model as proposed by Valentine (Valentine, 1991).

Finally, research on the differential processing of own- and other-race faces in regard to featural and configural information in faces provided further evidence for expertise-based accounts of the own-race bias. More specifically, several studies on the effect of expertise on the own-race bias provided evidence that not only configural (Michel, Rossion, Han, Chung, & Caldara, 2006b; Tanaka, Kiefer, & Bukach, 2004), but also featural (Rhodes, Hayward, & Winkler, 2006; Hayward, Rhodes, & Schwaninger, 2007) processing was enhanced for own-race as compared to other-race faces. Configural processing of faces (Maurer, Le Grand, & Mondloch, 2002) is thought to comprise the processing of first-order relations (the detection of a face-like composition of features, e.g. two eyes above a nose above a mouth), holistic face processing (integrating facial features into a holistic representation or gestalt) and second-order configural processing (analyzing the spatial relations between facial features in individual faces). Specifically second-order configural processing has been suggested to be critical for the processing of identity-relevant information in individual faces (Diamond & Carey, 1986), which in turn is necessary for the recognition of individual faces. This experience-driven fine-tuning of face processing mechanisms to faces of one’s own ethnicity has been suggested to explain discrepant

recognition memory accuracy to own- and other-race faces and its influence on the resulting own-race bias (Hancock & Rhodes, 2008; Rhodes et al., 2009).

In line with expertise-based accounts of the own-race bias, the own-race bias has been shown to be weakened in individuals with contact-induced expertise for other-race faces. However, it remains to be specified how much individuating contact may be adequate to significantly reduce the own-race bias and whether intensive individuation training over a relatively short period of time would suffice to create other-race expertise and therefore enhance recognition performance to other-race faces.

1.1.2 Socio-cognitive models of the own-race bias

In contrast to expertise-based explanations of the own-race bias, other theories stress the role of situational context and socio-cognitive processes on the perception of own- and other-race faces. From this perspective, the own-race bias is affected by a multitude of factors, such as differences in the arousal level elicited by own- and other-race faces (Maclin, Maclin, & Malpass, 2001), the categorization of a person as being an in-group or out-group member (Bernstein, Young, & Hugenberg, 2007; Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008), the saliency of affiliation to the same ethnicity as the observer (Young, Hugenberg, Bernstein, & Sacco, 2009) and the ethnic ambiguity of a given face (Maclin & Malpass, 2003). Furthermore, White American participants showed no recognition deficit for angry (Black American) faces (Ackerman et al., 2006), which has been attributed to the enhanced allocation of processing resources to threat cues. In line with this, the emotional state of the observer himself may serve to reduce the own-race bias (Johnson & Fredrickson, 2005). Finally, mixed evidence has been reported as to whether the categorization of a given ethnically ambiguous face as belonging to one's own or another ethnicity affects the own-race bias, with findings by Michel, Corneille & Rossion (2007) supporting this assumption, whereas a very recent series of experiments by Rhodes and colleagues did not observe such effects (2010).

Most prominently, Levin's race-feature hypothesis (Levin, 1996) assumes that the detection of an other-race specifying feature (such as dark facial skin for a Caucasian observer) may signal affiliation of a given face to an ethnic out-group and therefore lead to inferior coding of other-race faces. This in turn debilitates accurate recognition of other-race faces. According to the race-feature hypothesis, inferior recognition memory for other-race faces is the result of predominantly processing isolated category-defining features in other-race faces at the cost of individuating

facial information (Levin, 2000). On the contrary, own-race faces lack other-race specifying features and are therefore suggested to be processed at an individual level, which allows for the coding of individuating facial information and hence superior recognition accuracy. According to the race-feature hypothesis, a critical point is that individuals do not fail to code individuating information in other-race faces because they *can't*, but rather because they simply *don't* (see Levin, 2000, p. 571). It has been suggested that prompting observers to process faces at a deeper level should serve to improve recognition performance (Sporer, 1991). In line with this it could be assumed that the own-race bias should be lowered or even abolished when motivating observers to process other-race faces at a deeper and more individual level, possibly by solely changing the learning task in a recognition memory paradigm in such a way as to induce more individual-level encoding of own- and other-race faces.

In sum, the presented theoretical viewpoints on the own-race bias differ in regard to the suggested cause and the proposed persistency of the own-race bias. Socio-cognitive accounts assume that the own-race bias may be alleviated or even abolished under conditions beneficial for optimally encoding other-race faces or when stimulating observers to process other-race faces at a more individual level. On the other hand, expertise-based accounts to the own-race bias assume that experiences with faces from the observer's own ethnicity induce an own-race bias in observers, which can only be overcome by acquiring expertise with other-race faces through perceptual experiences and individuating contact.

1.2 Neuronal correlates of face processing

Whereas the own-race bias is a purely behavioral measure of own- and other-race face recognition memory, which can only measure the outcome of face processing mechanisms, electrophysiological methods such as event-related potentials (ERPs) allow for detailed chronometric assessment of the neural mechanisms that mediate different processing stages in face perception and memory (Rugg & Coles, 1995; Eimer, 2000b). ERPs may therefore represent an essential aide in illuminating the underlying mechanisms and differences in own- and other-race face processing.

1.2.1 P1

The earliest ERP component of interest in the context of face processing is the P1 component, a positive deflection over occipital areas with a maximal peak at about 100 ms after stimulus onset. P1 has been interpreted as being sensitive to basic visual stimulus properties, such as contrast, luminance or spatial frequency (Schendan, Ganis, & Kutas, 1998) and has thus been assumed to reflect early visual processing (Luck, 2005). Despite its sensitivity for low-level stimulus characteristics, P1 has also been found to be affected by top-down processing such as spatial attention (Hillyard, Vogel, & Luck, 1998) and arousal (Vogel & Luck, 2000).

Among the numerous studies on face perception and its neural correlates, a few studies reported increased P1 amplitudes to rotated and inverted faces as compared to upright faces (Itier & Taylor, 2002; Itier & Taylor, 2004; Jacques & Rossion, 2007a), to atypical as compared to prototypical faces (Halit, de Haan, & Johnson, 2000) and to faces as compared to objects (Herrmann, Ehlis, Ellgring, & Fallgatter, 2005). However, these effects are inconsistent with findings from the majority of studies on face processing and may, at least in part, be attributed to attentional modulations (Rossion et al., 1999a) or low-level stimulus properties (Rossion & Jacques, 2008). Still, further studies are necessary to resolve the question of the involvement of the P1 component in face processing and its sensitivity to high-level stimulus properties.

1.2.2 N170

Representing presumably the most often examined ERP component in the face processing literature, the N170 is a negative deflection over occipito-temporal areas, peaking at approximately 170 ms after stimulus onset (Boetzel, Schulze, & Stodieck, 1995; Bentin, Allison, Puce, Perez, & McCarthy, 1996). N170 has been found to be larger to face stimuli in comparison to other stimulus categories (Carmel & Bentin, 2002). Although having initially been described as eliciting a maximal peak over the right hemisphere (Bentin et al., 1996), several subsequent studies did not observe significantly greater N170 amplitudes over the right as compared to the left hemisphere (Bentin & Deouell, 2000; Eimer, 2000a; Rossion et al., 2000). Subsequently, it has been shown that N170 is elicited by largely impoverished face-like stimuli, such as schematic faces (Carmel & Bentin, 2002; Sagiv & Bentin, 2001), but is often assumed to be unaffected by familiarity of faces (Bentin & Deouell, 2000; Eimer, 2000b; but see Caharel et al., 2002), stimulus repetition (Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002; Eimer, 2000b; but

also see Heisz, Watter, & Shedden, 2006; Itier & Taylor, 2002) or attention (Cauquil, Edmonds, & Taylor, 2000; Mohamed, Neumann, & Schweinberger, 2009; but also see Jacques & Rossion, 2007b). Consequently, N170 has been interpreted to reflect early stages of structural encoding of faces (Bentin & Deouell, 2000; Cauquil et al., 2000; Eimer, 2000c) and the detection of a face-like stimulus pattern (Schweinberger & Burton, 2003). A more recent study additionally suggests a role of the N170 in the identification of social category information in faces (Freeman, Ambady, & Holcomb, 2010).

It has been suggested that N170 is specifically sensitive to faces, an assumption based on the finding of generally greater N170 to faces as compared to other stimulus categories (such as objects, Carmel & Bentin, 2002). However, evidence from a number of studies on the effect of expertise with a certain stimulus class suggests that N170 may instead be an index of subordinate-level expertise (Bukach, Gauthier, & Tarr, 2006; for a review, see Rossion, Curran, & Gauthier, 2002a; but also see Bentin & Carmel, 2002). In line with this, face-like N170 components were reported in experts when pictures of their objects of expertise (such as dogs or birds) were presented (Tanaka & Curran, 2001) and in non-experts when investigated after extensive training with artificial so-called "Greeble" stimuli (Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002b).

Importantly, N170 has been observed as being delayed and enhanced to the presentation of picture-plane inverted faces as compared to upright faces (Eimer, 2000a; Itier & Taylor, 2002; Latinus & Taylor, 2006; Rossion et al., 1999b; Rossion et al., 2000). On a behavioral level, inversion of faces has been found to severely impact recognition performance (the face inversion effect, cf. Yin, 1969) and is thought to disrupt the processing of configural information in faces (for a review, see Rossion, 2008). As a result, N170 has been interpreted to be sensitive to the configural processing of faces, specifically in regard to both first-order configurations and holistic information (Latinus & Taylor, 2006).

Most interestingly and inherently relevant in the context of this thesis, N170 has been associated with the differential processing of own- and other-race faces. However, observations regarding the nature of these ethnicity-dependent N170 effects are equivocal at best, with earlier studies reporting *no* ethnicity-dependent N170 amplitude differences at all (Caldara, Rossion, Bovet, & Hauert, 2004) or enhanced N170 amplitudes to *own-race* faces (Caldara et al., 2003; Ito & Urland, 2005). Whereas the latter findings of greater N170 amplitudes were recorded at either atypical electrode locations (Caldara et al., 2003) or with atypical reference settings (Ito & Urland, 2005), more recent studies observed enhanced N170 amplitudes to *other-race* faces (Herrmann et al., 2007; Walker, Silvert, Hewstone, &

Nobre, 2008). Whereas the reason for these discrepant findings remains yet to be determined, it is important to note that all studies reporting enhanced N170 peaks to other-race faces utilized various tasks in which participants had to explicitly process faces for identity. Interestingly, these findings are in line with a related study on the processing of typical and atypical face stimuli, which reported enhanced N170 amplitudes to atypical faces as compared to typical faces when participants attended to faces of different individuals (Halit et al., 2000). Since other-race faces differ systematically from own-race faces and are less frequently encountered, they may therefore be regarded as atypical in comparison to own-race faces. Thus, the latter findings of enhanced N170 to atypical faces can be interpreted as being in line with the findings of increased N170 amplitudes to other-race faces.

Taken together, these ambiguous findings on the N170 ERP component demonstrate that it is still not entirely clear whether ethnicity affects perceptual processing and structural encoding of own- and other-race faces in the N170 time range.

1.2.3 P2

Subsequent to the N170, an occipito-temporal P2 has been characterized as a positive-going peak over lateral occipito-temporal scalp areas with a maximum positive deflection at approximately 200-250 ms after stimulus onset. P2 has been shown to be increased to typical as compared to spatially distorted, atypical faces (Halit et al., 2000), to photographic as compared to two-tone Mooney faces (Latinus & Taylor, 2006) and to normal as compared to Thatcherized faces (Milivojevic, Clapp, Johnson, & Corballis, 2003). Taken together, P2 appears to be involved in the processing of spatial relations between facial features in individual faces (Latinus & Taylor, 2006) and has therefore been linked to the initiation of individual recognition mechanisms (Halit et al., 2000).

Interestingly, P2 has been found to be greater to young as compared to old faces in young participants in a recognition memory test (Wiese, Schweinberger, & Hansen, 2008). In that vein, one could argue that P2 may be sensitive to the perceived typicality of face stimuli in regard to a prototype and may therefore be influenced by perceptual expertise with a certain group of faces, e.g. expertise for young and Caucasian faces by Caucasian students. It has been assumed that expertise with a a certain stimulus class induces a greater ability to encode 2nd-order configural information (Diamond & Carey, 1986) and that the use of configural information in faces may be associated with the degree of expertise for a given class of faces

(Rhodes, Brake, Taylor, & Tan, 1989). In line with this suggestion, Mercure and colleagues (Mercure, Dick, & Johnson, 2008) found greater P2 amplitudes to faces with slight modifications of second-order relations as compared to the original faces or faces with a feature modification. The authors argued that perceptual expertise might increase the depth of processing for objects of expertise, which in turn may reflect the extraction of multiple levels of information (including configural information), all of which are necessary for the discrimination of these stimuli at an individual level (Mercure et al., 2008).

Since P2 has been suggested to be sensitive to the perceived typicality of faces in regard to perceptual categories and to the processing of second-order configural information, it appears plausible that P2 may be sensitive to processing own-race as compared to other-race faces and may constitute an ERP marker for differential configural processing of own- and other-race faces.

1.2.4 N250r/N250

The N250r, a negative component subsequent to the P2, has been described as a relatively more negative waveform for repeated as compared to unrepeated faces, typically peaking between 230 and 330 ms over right inferior temporal regions (Schweinberger, Pfutze, & Sommer, 1995; Begleiter, Porjesz, & Wang, 1995). The so-called N250r effect ("r" for repetition) has been found to be greater to familiar as compared to unfamiliar faces (Pfutze, Sommer, & Schweinberger, 2002; Herzmann, Schweinberger, Sommer, & Jentzsch, 2004) and as being delayed to inverted and contrast-reversed faces (Itier & Taylor, 2004). The latter finding was interpreted as reflecting more difficult access to configurally altered face representations. As a result from consistent findings of N250r effects, this component has been linked to the activation of structural face representations (Schweinberger & Burton, 2003). Despite these findings on a general repetition effect in N250r, previous studies reported no effect of ethnicity when repeatedly presenting own- and other-race faces (Herrmann et al., 2007). Still, an N250 component with a similar topography has been reported to be sensitive to the acquisition of face representations over a longer period of time. This component was observed to increase over time during learning of previously unfamiliar faces (Tanaka, Curran, Porterfield, & Collins, 2006; Kaufmann, Schweinberger, & Burton, 2009). In that line, a recent study on the effects of individuation training on other-race face processing reported increased N250 amplitudes as a result of individuation, but not categorization training (Tanaka & Pierce, 2009). In light of these sparse findings of an possible effects of ethnicity on

N250, further evidence for differential processing of own- and other-race faces and moderating factors is needed to clarify the connection between N250 and the processing of ethnicity-related information in faces.

1.2.5 LPC and the old/new-effect

For later stages of face processing, two components are of interest in regards to studies on the perception and recognition of own- and other-race faces.

Firstly, a late positive complex (LPC) which is characterized by a positive deflection over centro-parietal areas starting at approximately 400 ms after stimulus onset (Bobes, Valdessosa, & Olivares, 1994) has been shown to be larger to own-race faces as compared to other-race faces in an oddball-paradigm (Ito & Urland, 2003). In contrast to that, other-race faces elicited higher LPC amplitudes than own-race faces when presented in both upright or inverted position during test phases in a recognition memory experiment (James, Johnstone, & Hayward, 2001). The authors interpreted their finding as a greater allocation of processing resources to the more novel and less frequently experienced other-race faces, thereby reflecting increased modification of the (own-race) face norm used in encoding.

Secondly, experiments from the field of word recognition memory were able to show that learned ("old") stimuli elicited enhanced amplitudes compared to new stimuli, an effect starting at approximately 400 ms after stimulus onset. This old/new effect has been described as being maximal over left parietal electrodes to words (Rugg & Coles, 1995) and has been linked to the conscious recollection of episodic memory (for a review, see Rugg & Curran, 2007). More specifically, the old/new effect has been shown to be sensitive to the amount of recollected information, with higher amplitudes for those test items for which more information was recalled from episodic memory (Vilberg, Moosavi, & Rugg, 2006). Most importantly, it has also been shown that a comparable old/new effect can be observed during face recognition as well (Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000; Paller et al., 2003). Interestingly, as compared to the left parietal maximum for word stimuli, this old/new effect for faces has been reported to be more widely distributed over the scalp (Yick & Wilding, 2008) and has thus been suggested to reflect distinct cognitive operations when remembering names and faces (MacKenzie & Donaldson, 2009). Furthermore, the old/new effect has been proposed to differ in topography in regard to recollecting as compared to remembering faces (MacKenzie & Donaldson, 2007).

In line with these findings, the effect of face ethnicity on the old/new effect remains to be clarified. If the behavioral own-race bias were the result of more difficult access to representations of other-race faces in memory and hence associated with differences in retrieval of own- and other-race faces, one would expect differential old/new effects to own- and other-race faces. If however, the own-race bias were primarily driven by inferior encoding of faces into memory as opposed to retrieval of faces from memory, facial ethnicity should not modulate the old/new effect.

1.3 Research objective of the current thesis

In light of the theoretical viewpoints described above, the objective of this thesis was to examine several determinants of the own-race bias and neural correlates of own- and other-race face processing. More specifically, the influence of ethnicity, experience, situational demands and training on recognition memory performance for both own- and other-race faces were analyzed and related to predictions of expertise-based accounts and socio-cognitive theories of the own-race bias. However, differences in regard to the processing of faces from different ethnicities are not only evident on the behavioral level, but may also be observed in neural correlates of face processing. Differential processing of own- and other-race faces may be reflected by discrepancies in the configural processing of faces, which in turn has been reported to be severely disrupted by inversion. Therefore, the examination of the influence of ethnicity, experience and situational demands on configural processing and the ERP most widely discussed in face processing, the N170, as well as the P2 ERP component is one of the core interests of this thesis. Furthermore, investigating the influence of ethnicity on the old/new effect may help to elucidate the underlying cause of the own-race bias. More specifically, the research reported in this thesis shall provide conclusive evidence for the question whether the own-race bias results from discrepancies in encoding own- and other-race faces into memory, from differential retrieval of own- and other-race faces from memory or whether it is caused by retention problems of other-race face representations in memory.

Therefore, several aspects of the own-race bias and ethnicity-dependent differences in neural mechanisms of own- and other-race face perception were examined in the following studies:

Study 1: Expertise and the own-race bias: an event-related potential study (Stahl, Wiese, & Schweinberger, 2008); Note that the data presented in this study were

actually collected within the scope of my preceding diploma thesis. The subsequent journal paper, which was written in the early stage of my PhD, has been included in this thesis for reasons of completeness. Study 1 aimed at assessing the influence of expertise in participants with limited individuating other-race contact on the general own-race bias in comparison to non-experts. Furthermore, ERPs were measured to account for the effects of ethnicity and expertise on own- and other-race face processing.

Study 2: Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance (Stahl, Wiese, & Schweinberger, 2010): an investigation of the effect of learning task modulations in a recognition memory experiment on the behavioral own-race bias and ERPs to own- and other-race faces.

Study 3: The effect of individuation training on recognition performance and ERP-correlates of the own-race bias (Stahl, Wiese, & Schweinberger, submitted): in this study, a group of initially naïve participants were trained to individuate own- and other-race faces. To test for a generalized effect of training on the own-race bias, recognition memory experiments were conducted before and after training. In addition, ERPs to own- and other-race faces were recorded in both sessions and analyzed for effects of training and ethnicity.

Study 4: Configural processing of other-race faces is delayed but not decreased (Wiese, Stahl, & Schweinberger, 2009): in order to examine differences in the configural processing of own- and other-race faces, ERPs were recorded while subjects viewed own- and other-race faces that were presented in both upright and inverted positions. ERPs to own- and other-race faces were analyzed in regard to effects of ethnicity and inversion as well as in comparison to non-human face (ape faces) and object (houses) control stimuli.

The following chapter will provide an overview and short summaries of each individual study. In the subsequent discussion section, findings from the different studies will be compared and assessed in relation to their impact on the interpretation of the own-race bias and ERPs of face processing. Finally, an integrative model of the functional relevance of different processing stages and ERPs for the processing of own- and other-race faces will be proposed.

For detailed information on a particular study, please refer to the articles (studies 1, 2 and 4) and manuscript (study 3) attached to this thesis (appendix A-D).

2 Studies

2.1 Expertise and own-race bias: an event-related potential study (Stahl et al., 2008)

According to expertise-based explanations of the own-race bias, perceptual learning and lifetime expertise with primarily one ethnicity of faces shapes an observer's multi-dimensional face space (Valentine, 1991). More specifically, experience shapes an individual's face space in a way that is optimally suited to discriminate between individual faces from one's own ethnic group, thereby causing less accurate representations of other-race faces. At the same time, numerous studies were able to show that contact with other-race individuals may lower or even alleviate the own-race bias. Whereas some studies were able to demonstrate general effects of contact (Chiroro & Valentine, 1995; Slone, Brigham, & Meissner, 2000; Wright, Boyd, & Tredoux, 2003) with lower own-race bias usually found in participants reporting a higher level of contact with other-race individuals, several findings specifically argued for individuating contact with other-race individuals as being a critical factor for enhanced recognition performance to other-race faces (Walker & Hewstone, 2006b; Walker & Hewstone, 2008). Even though several studies were able to show an influence of long-term individuating contact (Chiroro & Valentine, 1995; Sangrigoli et al., 2005), only few studies (Hancock & Rhodes, 2008; Rhodes et al., 2009) have targeted the nature and development of expertise with other-race faces.

Whereas the own-race bias is a purely behavioral measure to assess the outcome of perceptual processing, ERPs allow for a temporally fine-grained investigation of the processes involved in the perception and recognition faces (Bentin et al., 1996). The N170, a prominent ERP component in face perception studies, has been interpreted to reflect the structural encoding of faces (Eimer, 2000c). As detailed above, evidence as to whether N170 may be influenced by the ethnicity of a given face is inconsistent. It therefore remains to be determined whether N170 is affected by face ethnicity and if so, in what direction. Apart from the N170, the P2 is a second ERP component that has recently been linked to the processing of perceptual category information and may therefore also reflect differential configural processing of own- and other-race faces.

The current study aimed at investigating the degree to which limited individuating contact with other-race faces affects the behavioral own-race bias. Furthermore, the study examined the influence of ethnicity and expertise with other-race faces on ERPs elicited by own- and other-race faces in two groups of Caucasian participants.

Whereas one group of participants (the control group) reported little to no previous contact with other-race individuals, a second group of participants (the expert group) had acquired individuating experiences with a limited number of people from another ethnicity (Chinese) over several years.

All participants completed a recognition memory experiment in which they had to learn and later recognize faces from individuals of their own (Caucasian) and another ethnicity (Asian). During learning phases, participants were required to first categorize the ethnicity of each of these faces and then memorize the respective faces. During the ensuing test phases, all faces from the directly preceding learning phase and new faces were presented, while participants were instructed to make speeded old/new responses. During the course of the experiment, EEG was recorded. ERP data from two lateral occipito-temporal recording sites were analyzed separately for old Caucasian faces (hits), new Caucasian faces (CR), old Asian faces (hits) and new Asian faces (CR).

Analyses of behavioral responses (accuracies) during test phases showed effects of both face ethnicity and other-race expertise on recognition accuracy. Whereas *d'* were higher to Caucasian faces as compared to Asian faces in both groups, group comparisons also revealed that participants from the expert group exhibited generally higher *d'* than participants from the control group. Moreover, follow-up analyses demonstrated a significantly lower own-race bias (calculated as the difference between d' to own- and other-race faces and standardized for a participant's overall face recognition accuracy, according to Macmillan & Creelman, 1991) for experts as compared to the control group (see Stahl et al., 2010).

In addition, both face ethnicity and experience also had an influence on ERPs to own- and other-race faces. Other-race faces elicited more negative and delayed N170 peaks in both groups, possibly indicating enhanced configural processing of own- compared to other-race faces. Most intriguingly, however, the subsequent P2 component was modulated by the participant's amount of expertise with other-race faces. Whereas P2 mean amplitudes were more positive to own-race faces over both hemispheres in the control group, this P2 amplitude difference between own- and other-race faces was absent over the right hemisphere in the expert group. Since increased amplitudes in the P2 component have been attributed to second-order configural processing (Latinus & Taylor, 2006), these findings in P2 were interpreted as representing more expert-like processing and configural coding of other-race faces in the experts.

In summary, these findings suggest a reduction of the own-race bias by individuating contact with even a limited number of other-race individuals. Furthermore, ERP evidence for more expert-like neural processing of other-race

faces in the P2 component argues for expertise-dependent effects on second-order configural processing mechanisms of the own-race bias.

2.2 Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance (Stahl et al., 2010)

It has been demonstrated that expertise exerts a major effect on memory for own- and other-race faces and thus the own-race bias. As described above, the own-race bias is modulated by long-term expertise acquired over the lifetime (Walker & Hewstone, 2006a) and contact with other-race individuals (Chiroro & Valentine, 1995).

In contrast to these expertise-based accounts, other theories stress the role of situational context and socio-cognitive processes on the own-race bias. More specifically, it has been shown that the own-race bias may be affected by a variety of factors, such as the categorization of a person as an in-group or out-group member (Bernstein et al., 2007; Shriver et al., 2008). Additionally, even though empirical evidence suggests more holistic processing of ethnically ambiguous faces perceived as belonging to the observer's own ethnicity (Michel, Corneille, & Rossion, 2007), enhanced processing of ambiguous-race faces perceived as own-race faces appears to be inadequate to effectively improve perceptual discrimination accuracy as well as recognition memory in the context of the own-race bias (Rhodes, Lie, Ewing, Evangelista, & Tanaka, 2010).

Most importantly, Levin's race-feature hypothesis (Levin, 1996) assumes that the detection of an other-race specifying feature leads to inferior coding of other-race faces, which in turn debilitates accurate recognition of these faces. It is assumed that this inferior processing of other-race faces is primarily driven by the processing of isolated category-defining features at the cost of individual facial information (Levin, 2000), whereas own-race faces are suggested to be processed at an individual level, which allows for superior recognition accuracy. Critically, individuals do not fail to code individuating information in other-race faces because they are not *able* to do so, but rather because they simply *do* not process individuating information (see Levin, 2000, p. 571). In conclusion, whereas expertise-based models argue for a lack of long-term perceptual expertise to underlie the own-race bias, socio-cognitive theories predict a beneficial effect of prompting an observer to process other-race faces at a deeper and more individual level (cf. Sporer, 1991).

The aim of the current experiment was to differentiate between these two theoretical assumptions and to determine the effects of different task demands during

encoding on the own-race bias. Two groups of naïve Caucasian participants learned own- and other-race faces either with a task stressing the discrimination of faces within ethnic groups (attractiveness rating on a 6-points scale) or between ethnic groups (ethnicity categorization). In a subsequent test phase, participants from both groups were required to differentiate learned ("old") from unfamiliar ("new") faces. If situational context were to affect the own-race bias, encoding demands that stressed processing of more individual-level information in other-race faces (attractiveness rating) should result in a decreased or even abolished own-race bias. If however, the own-race bias could only be affected by long-term perceptual expertise, no effects of learning task should be apparent in participants who lack extensive experience with other-race faces. In addition, ERPs to own- and other-race faces were recorded during learning and test phase and analyzed for effects of ethnicity and learning task.

Analyses of behavioral responses during test phases demonstrated significantly higher recognition memory performance to Caucasian as compared to Asian faces in both groups of participants. However, the own-race bias (calculated according to Macmillan & Creelman, 1991) did not differ between groups. This suggests that a change in learning task may not be sufficient to abolish or decrease the own-race bias in naïve participants without prior expertise regarding other-race faces.

An early effect of ethnicity on ERPs during learning phases was observed in the N170, which was delayed (over both hemispheres) and enhanced (over the right hemisphere) for Asian faces. Interestingly, mean amplitudes in the subsequent P2 ERP component showed ethnicity-dependent differences that were modulated by learning task. Whereas significantly more positive-going amplitudes were observed to Caucasian faces in the categorization group, no such differences were visible in the attractiveness rating group. Additionally, analyses of a subsequent late positive complex (LPC, 400-600 ms) showed generally enhanced mean amplitudes to Asian faces over parietal electrodes in the categorization group, whereas no ethnicity-dependent amplitude differences were evident in the attractiveness rating group.

Analyses of ERPs during test phases confirmed the differences between Asian and Caucasian faces found in the learning phases. N170 was delayed and enhanced to Asian faces in both groups. In addition, participants from the categorization group exhibited more positive-going P2 mean amplitudes to Caucasian faces over both hemispheres, whereas this amplitude-difference was absent over the left hemisphere in the attractiveness rating group. Finally, analysis of the old/new-effect (400-600 ms) revealed significantly more positive mean amplitudes to old faces in both groups. However, this main effect of face ethnicity was further qualified by an interaction with learning task, since participants from the attractiveness rating group

exhibited a significantly increased old/new-effect to Caucasian faces, whereas no such ethnicity-dependent modulations of the old/new-effect were observed in the categorization group.

Taken together, the current findings argue for an effect of the learning task on ERP correlates of the own-race bias, as evidenced in the diminished P2-amplitude effects in the attractiveness rating condition. Moreover, this P2 effect of learning task was not only visible during learning phases, but also during test phases. Importantly, this apparently similar processing of own- and other-race faces in the P2 component of the attractiveness rating group during learning and test phases was not paralleled by better recognition performance for other-race faces. Still, the enhanced old/new-effect for own-race faces in the attractiveness rating condition would seem to suggest that participants may have been able to retrieve more episodic knowledge for own-race as compared to other-race faces, since higher amplitudes in the old/new effect were suggested to reflect the retrieval of more information from episodic memory (Vilberg et al., 2006). Thus, comparable ERP results for own- and other-race faces in the attractiveness rating group but not in the categorization group during learning phases argue for similar encoding of these faces. However, neither memory related ERPs in the test phases (i.e., the old/new-effect) nor behavioral measures of recognition memory performance suggest that participants could benefit from this relatively better encoding. While this contradicts the assumption of the own-race bias as an encoding-based phenomenon (Meissner, Brigham, & Butz, 2005), it is in line with the suggestion that retrieval deficits may elicit inferior recognition performance to other-race faces and thereby caucse the own-race bias (Papesh & Goldinger, 2009).

To conclude, the present study demonstrated that task demands during learning may induce similar ERP correlates of own- and other-race face processing during both learning and test phases. It could be argued that observers in the attractiveness rating condition encoded relatively *more* facial information for other-race faces (as seen in similar processing in the P2/LPC ERP components) as compared to participants in the categorization group. However, own- and other-race faces may qualitatively differ in regard to those facial characteristics that are critical for recognition (cf. Shepherd & Deregowski, 1981; Blais et al., 2008). It thus appears likely that this surplus information may not have been beneficial to other-race face recognition, because the *same type* of information was extracted for own- and other-race faces – information, that may be highly diagnostic for identifying own-race faces, but not for other-race faces. These participants' inability to later benefit from a learning task that apparently allowed for more differential face processing may be due to a lack of previous experience with other-race faces and, according to

expertise-based accounts of the own-race bias, to the inability to adequately store other-race faces in face space. I therefore conclude that even though task demands may have an effect on the neural processing of own- and other-race faces, long-term perceptual expertise with other-race individuals appears to be a necessary prerequisite for improved other-race face recognition memory and, to that effect, for a lowered own-race bias.

2.3 Effects of Training on ERP-correlates of the Own-Race Bias in Face Recognition (Stahl et al., submitted)

The own-race bias in face recognition has been mostly attributed to life-long perceptual learning and experience with faces, the majority of which are typically from the observer's own ethnicity (see section 1.1.1). Empirical evidence further demonstrated that the own-race bias is weakened in individuals with expertise for other-race faces (Chiroro & Valentine, 1995). Accordingly, this reduced own-race bias is primarily found in individuals reporting a large amount of individuating contact with other-race individuals, as opposed to more superficial contact (Slone et al., 2000). In line with this, a recent study (Tanaka & Pierce, 2009) tried to establish expertise with other-race faces by training participants to learn faces from two different ethnic "out-groups". Participants were trained to differentiate faces from one ethnic group in a categorical way (all faces of that group were labeled with the same letters) and faces from another ethnic group in an individual way (individual faces were labeled with unique letters). Comparison of recognition performance measured before and after training indicated increased recognition accuracy for the face ethnicity learned at an individual level, whereas no effect of training was observed for faces learned at the categorical level. These findings indicate that training may improve recognition performance for other-race faces.

The current study sought to further elucidate the effect of training on both own- and other-race face recognition and the own-race bias. According to previous studies (Goldstein & Chance, 1985; Lebrecht, Pierce, Tarr, & Tanaka, 2009; McKone, Brewer, MacPherson, Rhodes, & Hayward, 2007; Tanaka & Pierce, 2009), training is assumed to positively affect performance when recognizing other-race faces. In contrast to that, individuation training on own-race faces should have little or no effect (cf. Sporer, 1991, p. 330) since a massive amount life-time experience is thought to shape an individual's face space to optimally store own-race faces. I therefore expected to observe a lower own-race bias after a number of intensive learning sessions in which participants were trained to differentiate between

individual own- and other-race faces. In regard to ERP correlates, I expected a latency reduction after training in the absence of other training-induced effects in the N170 (see Tanaka & Pierce, 2009). In addition, findings from Tanaka and Pierce (2009) showed an effect of training on the posterior N250 component, in that subordinate-level, but not categorization training caused increased N250 amplitudes. The authors assumed that the N250 may therefore reflect the formation of perceptual representations that allow for improved discrimination accuracy as a result of expertise established by subordinate-level training. In line with this, one may assume that individuation training on own- and other-race faces may evoke more similar processing of these faces in the N250.

To test for training effects on the own-race bias, a group of participants without intensive prior experience regarding Asian (other-race) faces completed an initial recognition memory experiment to assess the individuals' baseline performance for same- and other-race face recognition memory. Subsequently, all participants attended five training session, in which they learned to individuate own- and other-race faces. Finally, a second recognition memory experiment was conducted to measure recognition accuracy for own- and other-race faces after training (see Fig. 2 for a schematic description of the experimental sessions).

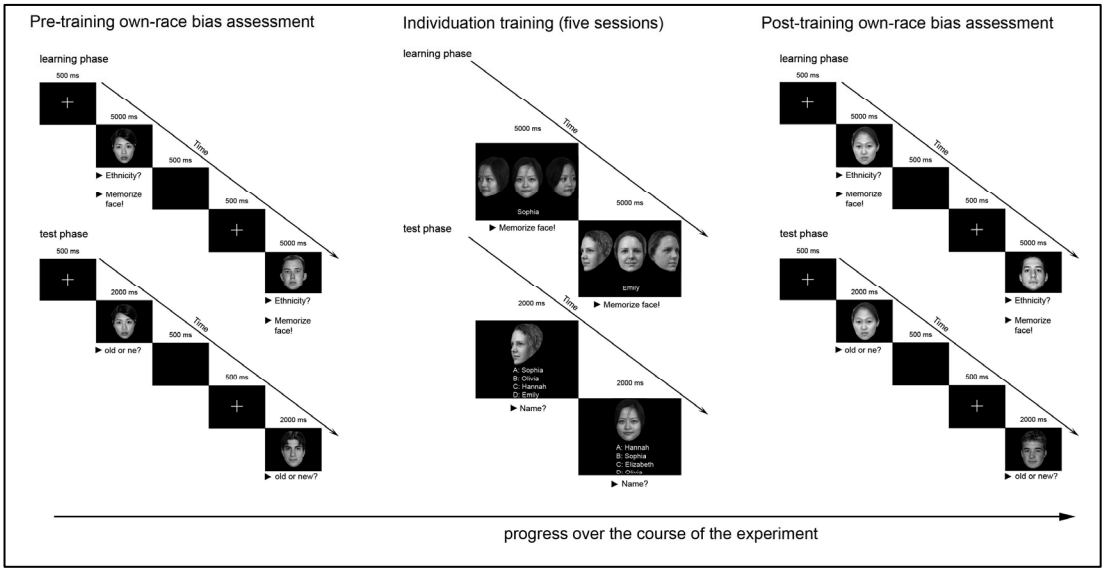

Figure 2: schematic overview over the sequence of experimental sessions, with pre-training own-race bias assessment, individuation training sessions and post-training own-race bias assessment (from: Stahl, Wiese & Schweinberger, submitted)

In order to test for a generalized effect of training on the own-race bias for previously unseen faces, stimuli for pre- and post-training recognition memory tests comprised two distinct sets. The five individuation training sessions were spaced over a maximum of two weeks, while ideally being held on five consecutive days.

During each training session, participants were required to memorize and correctly recognize the names and faces of 16 individuals represented by pictures from several different angles, half of which were Asian and Caucasian, respectively. During both pre- and post-training recognition memory experiments, 32-channel-EEG was recorded.

As a result of training, a decreased own-race bias was observed in post-training assessment as compared to pre-training assessment. Surprisingly however, this change in the recognition memory difference between Caucasian and Asian faces (the underlying own-race bias) was due to significantly reduced recognition memory to Caucasian faces after training. By contrast, no effect of training was observed for Asian faces. Furthermore, analysis of response bias indicated more conservative responses to Asian faces after training. At the same time, no significant effects of training were obtained on measures of response bias to Caucasian faces, even though a trend for more liberal responses to Caucasian faces was detected.

Whereas analysis of N170 and P2 in learning phases of the pre- and post-training recognition memory experiments yielded no effects of an interdependency of ethnicity and training effects, these results were consistent with earlier findings of ethnicity-dependent modulations of N170 latency (Stahl et al., 2008; Stahl et al., 2010) and amplitude (Herrmann et al., 2007; Stahl et al., 2008; Walker et al., 2008; Stahl et al., 2010) as well as P2 amplitude (Stahl et al., 2008; Stahl et al., 2010). On the contrary, analysis of ERPs in the test phases of pre- and post-training recognition memory experiments demonstrated an interaction of the effects of ethnicity and training on both N170 and P2. Whereas N170 was initially delayed and enhanced to Asian faces over the left hemisphere, individuation training induced a general decrease in N170 latency and a shift of ethnicity-dependent N170 effects to the right hemisphere, with more negative amplitudes to Asian faces over the right, but not over the left hemisphere following training. Intriguingly, analyses of the subsequent P2 component yielded a significant interaction of face ethnicity, hemisphere and pre- vs. post-training, indicating more positive-going mean amplitudes to Caucasian faces during pre-training assessment over both hemispheres. In contrast, this ethnicity-dependent difference in P2 mean amplitudes was abolished over the left hemisphere in the post-training assessment. Finally, analysis of the old/new-effect confirmed significantly more positive amplitudes to old as compared to new faces prior to training, but no ethnicity-dependent waveform differences after training.

Taken together, these findings demonstrate that individuation training for own- and other-race faces exerts an influence on both the behavioral own-race bias and ERPs reflecting own- and other-race face processing. Contrary to theoretical expectations of increased recognition performance to other-race faces, training

decreased memory performance to own-race faces, which in turn lead to a reduction of the own-race bias. Most importantly, training affected the lateralization of ethnicity-dependent differences in N170 and P2. In line with previous findings of a functional lateralization of the N170 (Scott & Nelson, 2006), the present shift in the lateralization of ethnicity-dependent differences in N170 amplitude from the left (pre-training) to the right hemisphere (post-training) may argue for training induced changes in the processing of own- and other-race faces. Whereas N170 over the left hemisphere has been linked to the processing of facial features, the right-hemispheric N170 has been attributed to configural face processing (Scott & Nelson, 2006). Thus, the observed lateralization shifts in N170 amplitude differences may suggest a training-induced shift from differential feature processing towards differences in the processing of configural information in Caucasian and Asian faces. In the same way, the absence of left-hemispheric ethnicity-dependent differences in P2 amplitude appears strikingly similar to P2 findings under the attractiveness rating condition in study 2 (Stahl et al., 2010). In contrast, the absence of right-hemispheric ethnicity-differences in P2 amplitude in experts (study 1) was paralleled by a significantly reduced behavioral own-race bias (Stahl et al., 2008; Stahl et al., 2010). Taken together, the P2 modulations elicited by differences in task demands or by individuation training may reflect changes in the strategic processing of own- and other-race faces, but do not necessarily affect the behavioral own-race bias. Moreover, the reduced own-race bias in experts and the absence of right-hemispheric ethnicity-dependent differences in P2 amplitude (study 1) may reflect similar second-order configural processing for faces of both ethnic groups. Finally, the training-induced deletion of ethnicity-dependent differences in the old/new effect suggests similar processing during retrieval of information on own- and other-race faces from memory, whereas no training effects were observed on encoding processes for own- and other-race faces as reflected in the LPC during learning phases. This argues for an influence of individuation training on retrieval, but not encoding processes. Furthermore, contrasting results of an influence of task demands on encoding processes in the LPC, but not retrieval processes as reflected in the old/new effect (study 2) and the absence of an effect on the own-race bias in both of these studies suggest that the lack of a training effect in the current study is presumably not (only) due to differential encoding of own- and other-race faces as apparent in the LPC in learning phases.

In sum, the behavioral and ERP findings from the present study argue for modulations in the processing of own- and other-race faces as a result of individuation training. In line with this, it could be assumed that participants became aware of the inherent discrepancies in the recognition of own- and other-race faces.

Training may therefore have induced participants to allocate more attention to other-race faces. Taken together with the impact of training on ERPs to own- and other-race faces and a lack of increased recognition accuracy to other-race faces, these findings do not seem to be in line with socio-cognitive accounts of the own-race bias, which assume that strategic changes in the processing of own- and other-race faces affect the own-race bias (Levin, 2000). Rather, the present results indicate that participants were not able to benefit from a change in strategic processing, possibly due to a lack of expertise with other-race faces. In light of this, these findings are compatible with accounts stressing the importance of long-term expertise on the own-race bias.

2.4 Configural processing of other-race faces is delayed but not decreased (Wiese et al., 2009)

A common finding in the previous studies on the own-race bias described above has been the effect of ethnicity on the N170 ERP component, with delayed and enhanced N170 peaks to other-race faces. Whereas this effect has been demonstrated in studies of other groups on own- and other-race face recognition as well (Herrmann et al., 2007; Walker et al., 2008), the exact cause of apparently differential perceptual processing of own- and other-race faces in the N170 time range remains to be clarified.

As previous research has illustrated, differential processing of own- and other-race faces may not only be reflected in recognition memory performance for faces of different ethnicities, but also in perceptual face processing mechanisms. It has been suggested that early perceptual face processing (or structural encoding, cf. Bruce & Young, 1986) involves several mechanism, namely first-order configural processing, holistic processing and second-order configural processing, all of which serve to cater to different aspects of configural face processing (Maurer et al., 2002) (see section 1.1.1, p. 6). Intriguingly, configural processing of faces has been shown to be disrupted by picture-plane inversion, resulting in severely decreased recognition accuracy to faces that have been turned upside-down (the face inversion effect, cf. Yin, 1969; for a review, see Rossion, 2008).

In regard to the perception and processing of own- and other-race faces, various studies have been able to demonstrate inferior perceptual processing of other-race faces. For instance, it has been shown that the Thatcher-effect is less pronounced in other-race than in own-race faces (Murray, Rhodes, & Schuchinsky, 2003). Since the Thatcher-illusion (i.e. faces with eyes and mouth rotated by 180° appear bizarre

when presented upright, but not after picture-plane inversion) has been interpreted as reflecting a deficit in configural processing, it has been hypothesized that configural processing is decreased in other-race faces. This assumption is supported by findings that holistic processing is more pronounced in own-race faces (Michel et al., 2006b; Michel, Caldara, & Rossion, 2006a; Tanaka et al., 2004). However, not only configural, but also feature processing appear to be superior for own-race faces as compared to other-race faces (Hayward et al., 2007; Rhodes et al., 2006).

Presumably representing a neural correlate of configural processing, N170 is typically delayed and enhanced to inverted as compared to upright faces (Eimer, 2000a; Itier, Latinus, & Taylor, 2006; Latinus & Taylor, 2006; Rossion et al., 1999b; Rossion et al., 2000). Thus, if other-race faces are processed less configurally, one would expect N170 to be delayed and enhanced to upright other-race as compared to own-race faces. As detailed in the studies mentioned above, this is indeed the case. However, all faces in these experiments were presented in an upright orientation. It therefore remains to be clarified, whether the N170 effect to other-race faces is due to decreased configural processing or caused by a different underlying process. Assuming that the N170 ethnicity effect was elicited by inferior configural processing of other-race faces, the N170 inversion effect to inverted other-race faces (as compared to own-race faces) would be expected to be diminished or even absent. If however, the inversion and the ethnicity effects in the N170 were independent from each other, one would expect an additive effect of inversion and ethnicity. Thus, the N170 latency delay caused by other-race as compared to own-race faces should be independent of, and in addition to, the latency delay (and amplitude increase) caused by inversion.

The current study aimed at testing these two competing predictions Participants in the experiment were presented with upright and inverted own- and other-race faces as well as two categories of control stimuli (ape faces as non-human face stimuli, as well as house fronts), both presented in upright and inverted orientations. Over the course of the experiment, EEG was recorded continuously and ERPs were analyzed for effects of stimulus type and orientation.

Analyses of N170 peak latencies yielded significant main effects of stimulus type and orientation as well as an interaction of these factors, indicating step-wise latency increases from own-race (earliest N170 peak) to houses (latest N170 peak). For face stimuli only (Asian, Caucasian and ape faces), inversion elicited significantly delayed N170 peaks as compared to upright stimulus presentation. Importantly, the effects of stimulus type and inversion did not interact for face stimuli. To test for the prediction of an additive effect of inversion and ethnicity on N170 latency, the N170 inversion effect was calculated separately for both human face categories.

Comparison of the magnitude of these effects yielded no significant differences, indicating comparable inversion effects on N170 latency to own- and other-race faces. A corresponding analysis on N170 amplitude for all stimulus categories and orientation conditions revealed significant main effects of stimulus type and orientation as well as a significant interaction of these factors, indicating significantly larger N170 amplitudes to face stimuli as compared to house fronts and a significant increase in N170 amplitude to inverted human faces as compared to upright human faces. In contrast, no inversion effects in N170 amplitude were observed for ape faces and house fronts, with house fronts eliciting the lowest N170 amplitudes among all stimulus categories.

In sum, the present findings on the effects of ethnicity and inversion on N170 latency and amplitude to faces revealed several findings. First, both other-race and other-species faces led to delayed N170 peaks, as seen in N170 to Asian and ape faces. Secondly, inversion additionally delayed N170 peaks to face stimuli, which was indistinguishably so for both own- and other-race faces. This finding is in line with the hypothesis of independent effects of ethnicity and inversion on N170 latency. Additionally, N170 amplitude was increased to inverted own- and other-race faces in the absence of a similar effect for other-species faces. Given the assumptions that configural and holistic processing of other-race faces is decreased (Michel et al., 2006a) and that inversion severely disrupts configural processing (Maurer et al., 2002), inversion of other-race faces should have elicited little to no increase in N170 latency. At variance with this prediction, the findings from the current study argue for the assumption of different processes as the basis of the N170 face inversion and the N170 ethnicity effect. They instead suggest that structural encoding of own- and other-race faces is not qualitatively different, but less efficient for other-race faces as compared to own-race faces. To that effect, less efficient processing of other-race faces may in turn be a critical contributing factor to the own-race bias in face recognition.

3 General discussion

The term “own-race bias” refers to the phenomenon that people are generally much better when recognizing faces from their own ethnic group as compared to faces from another ethnicity (Meissner & Brigham, 2001). Whereas several theories have been put forward to account for this effect in recognition memory, research on face perception has also provided evidence for fundamental differences in early neural correlates of own- and other-race face processing.

Accordingly, the scope of this thesis was to examine the influence of various factors on both the behavioral own-race bias and the neural correlates of the processing of own- and other-race faces. Over the course of several experiments, recognition accuracy to faces of different ethnicities and ERP correlates of face processing were recorded and analyzed in regard to the influence of perceptual expertise, task demands, individuation training and differences in configural processing on the perception and recognition of own- and other-race faces.

In order to account for the effects on the behavioral own-race bias and ERP correlates of own- and other-race face processing, this general discussion section will first focus on factors influencing the behavioral own-race bias (determinants of the own-race bias), before summarizing ERP findings on own- and other-race face processing (modulation of ERP correlates of the own-race bias). Finally, the implications from findings on both behavioral correlates and neuro-cognitive mechanisms of differential own- and other-race face perception will be integrated and discussed in relation to the initially proposed theoretical explanations of the own-race bias.

3.1 Determinants of the own-race bias

Within the scope of this thesis, the effects of expertise, task demands and individuation training on the own-race bias in face recognition were examined over the course of several experiments. In the following paragraphs, empirical findings on behavioral determinants of the own-race bias will be compared and assessed in relation to their impact on the interpretation of the own-race bias and their relevance for theoretical accounts of the own-race bias.

Theoretical explanations of the own-race bias can essentially be divided into two groups, namely expertise-based and socio-cognitive accounts of the own-race bias. Whereas expertise-based explanations of the own-race bias suggest that the

phenomenon is caused by experience-driven fine tuning of the memory system for faces of one's own race (Valentine, 1991; Valentine & Endo, 1992), socio-cognitive assume that situational context and socio-cognitive factors influence a person's ability or motivation to process and appropriately encode individual own- and other-race faces for later recognition. Hence, recognition accuracy to faces is assumed to depend on factors determined by the encoding situation. In contrast, expertise-based accounts assume that long-term experience shapes the own-race bias and that therefore only perceptual expertise gathered over a relatively long time with another ethnicity may affect other-race recognition accuracy.

To examine the influence of ethnicity, experience and situational demands and their relevance in regard to the theoretical models accounting for the own-race bias, several recognition memory experiments have been conducted over the course of this PhD and described in chapter 2.

Basically, the findings from this thesis are in line with empirical evidence accumulated over the course of the last decades (Meissner & Brigham, 2001), suggesting the own-race bias to be a very stable phenomenon. Correspondingly, results from all recognition memory experiments presented above confirm generally higher recognition performance for own-race as compared to other-race faces. Importantly, even though task demands (study 2) and training (study 3) elicited an effect on face processing as seen in ERPs to own- and other-race faces, only expertise with other-race faces acquired over several years exerted an effect on the behavioral own-race bias, which was reflected in decreased differences in recognition accuracy to own- and other-race faces in experts (study 1).

Importantly, the experts in study 1 acquired intensive individuating experiences with only a limited number of other-race (Chinese) individuals, thereby supporting claims that individuating contact but not mere "exposure" may be crucial for significant reduction of the own-race bias (Slone et al., 2000; Walker & Hewstone, 2006b; Walker & Hewstone, 2008). In line with these findings, several studies on the impact of training on other-race face processing reported improved recognition performance to other-race faces after training (Goldstein & Chance, 1985; Lebrecht et al., 2009; Tanaka & Pierce, 2009), which is in line with accounts suggesting perceptual learning as the basis of the own-race bias. However, no previous study tried to assess the impact of individuation training for both own- and other-race faces on the own-race bias and the degree to which training effects gained with a limited set of faces can generalize to a certain ethnicity of faces. Whereas intensive individuation training on other-race faces should enhance recognition performance for these faces in light of expertise-based explanations of the own-race bias, individuation training on own-race faces should exert little to no effect on

recognition memory performance for these faces (cf. Sporer, 1991, p. 330). Furthermore and in contrast to previous training studies, the utilization of previously unseen own- and other-race faces in the post-training recognition memory test in study 3 allowed testing for a generalized effect of training on recognition accuracy to faces from the observer's own and another ethnicity. Importantly, individuation training (study 3) did not improve recognition performance for other-race faces, but instead reduced recognition accuracy to own-race faces.

These changes in recognition accuracy to own-race faces may be interpreted as reflecting initial correlates of slight, but significant adaptations of an observer's face space to better accommodate other-race faces. Since face space is assumed to be highly specialized to faces of an observer's own ethnicity (Valentine & Endo, 1992), recognition performance for own-race faces may be especially vulnerable to changes in face space. Correspondingly, it appears plausible that training induced changes in face space that may serve to increase recognition memory for other-race faces, but at the same time debilitate memory for own-race faces. Training could therefore lead to modifications in face space that render it sub-optimally tuned for *both* accurate recognition of own-race faces and improved recognition memory performance for other-race faces. Based on these findings of short-term individuation training it may be hypothesized that training over a longer period of time should yield clearer results of a training effect on recognition performance to both own- and other-race faces. In line with previous considerations of the impact of training and expertise with other-race faces on face space, it could be hypothesized that (theoretically) training and other-race expertise would ultimately lead to a face space that is tuned to represent faces of different ethnicities equally well. Assuming that face space may be limited in regard to optimal representation of *all* faces, this processing limit may actually result in decreased quality of representation for the entirety of faces. This could be assumed to entail a decrease in recognition memory performance to own-race faces, since face space is no longer tuned to optimally represent these faces. As a result, training may not only lead to *better* representation of other-race faces, but also to *worse* representation of own-race faces in face space.

Alternatively, training could have also induced participants to shift their attention to information relevant for the discrimination of other-race faces, which may have been at the cost of encoding relevant information in own-race faces. These possible changes in strategic processing of own- and other-race faces did, however, not lead to better recognition of other-race faces and the findings from study 3 are thus not in line with socio-cognitive accounts of the own-race bias. Rather, a lack of other-race expertise and a resulting inability to accurately store individuating information for

other-race faces in memory may have evoked lower recognition accuracy to other-race faces, which corresponds to expertise-based accounts.

In addition to findings described above and in contrast with assumptions made by the race feature hypothesis (Levin, 1996; Levin, 2000), a study on the influence of the learning task on the own-race bias (study 2) reported no effect of directing participants' attention towards individual (non-race specifying) information as opposed to race-specifying features. Even though ERP findings argue for highly similar processing of own- and other-race faces during learning and test phases in the attractiveness rating group as compared to the categorization group, improved processing of other-race faces did not exert an effect on the own-race bias. This lack of a behavioral correlate argues against a purely socio-cognitive basis of the own-race bias, since participants were presumably not able to benefit from enhanced configural processing of other-race faces, probably due to a lack of expertise with other-race faces. Interestingly, in the attractiveness rating group, ERP findings of similar processing of own- and other-race faces in later stages of face processing during learning suggest comparable encoding of faces from different ethnicities. However, the enhanced old/new-effects for Caucasian as compared to Asian faces in test phases suggest the recollection of more detailed information for own-race faces, which is in line with assumptions from previous studies on the dissociation of recollection and familiarity in the recognition of own- and other-race faces (Marcon, Susa, & Meissner, 2009; Meissner et al., 2005). In line with this it could be assumed that even though participants in the attractiveness rating condition processed own- and other-race faces similarly and extracted a comparable amount of facial information during learning, this information was more beneficial to the recognition of own-race faces during test and may therefore explain the increased old/new effect for own-race faces in the attractiveness rating condition as reflecting facilitated recollection-based processing for own-race faces. Taken together, instead of providing support for socio-cognitive explanations of the own-race bias, the findings from study 2 are more in line with expertise-based accounts of the own-race bias (Valentine, 1991), suggesting that long-term perceptual expertise with other-race individuals may be a necessary precondition for improved other-race face recognition and a diminished own-race bias (Chiroro & Valentine, 1995).

As detailed above, both learning task manipulations and individuation training affected other-race processing. Whereas a change in the learning task induced more similar encoding of other-race faces during learning phases in participants under the attractiveness rating condition (study 2), individuation training elicited similar processing of own- and other-race faces during retrieval from memory (study 3). These findings may suggest that participants' attention was shifted towards the

processing of other-race faces. However, the lack of a behavioral effect in the form of a reduced own-race bias in both studies argues against explanations of the own-race bias as a purely encoding-based process (Meissner et al., 2005) or as being exclusively caused by difficulties in retrieval of information on other-race faces (Papesh & Goldinger, 2009). Moreover, the findings from the present thesis argue for retention problems as the cause of the own-race bias (Papesh & Goldinger, 2009), suggesting that inferior recognition memory performance to other-race faces may be due to difficulties in adequately storing these faces in memory as opposed to being solely due to either differential encoding or retrieval from memory.

Finally and with respect to findings of differential configural and/or holistic processing of own- and other-race faces (Murray et al., 2003; Tanaka et al., 2004; Michel et al., 2006b; Michel et al., 2006a; Hancock & Rhodes, 2008; Hayward, Rhodes, & Schwaninger, 2008), an examination of the effects of ethnicity and inversion (study 4) suggests that structural encoding may not be qualitatively different for other-race as compared to own-race faces. Instead, these processes appear delayed and less efficient for other-race faces, which in turn may underlie and contribute to inferior recognition memory performance for other-race faces and therefore the own-race bias.

In sum, the findings from the studies conducted and reported in the context of the present thesis are mostly in line with expertise-based accounts of the own-race bias, which assume that long-term expertise and perceptual experiences with own-race face result in improved processing of own-race faces and a memory system that is fine-tuned to accurate representations of faces of one's own ethnicity (Valentine, 1991; Valentine & Endo, 1992). Accordingly, only intensive expertise with other-race faces (study 1) exerted a significant effect on other-race recognition performance, whereas a modulation of strategic processing by a change in task demands (study 2) or individuation training (study 3) did not affect other-race recognition memory in non-expert participants.

3.2 Modulation of ERP correlates of the own-race bias

Whereas behavioral measures of recognition accuracy can only measure the outcome of perceptual processing, ERPs allow for temporally fine-grained analyses of even subtle differences in the processing of own- and other-race faces and the putative impact of long-term and situational changes in face perception.

Summarized below are the empirical findings on ERP correlates of ethnicity, expertise, training and task demands in the context of own- and other-race face processing.

3.2.1 P1

The P1 is generally interpreted as a sensory-evoked visual component which is sensitive for early pre-categorical selection during visual attention (Mangun, 1995), presumably altering the input to higher stages of visual processing. In regards to face processing, it remains to be clarified whether P1 may not only reflect the processing of basic visual stimulus properties (Schendan et al., 1998; Rossion & Jacques, 2008), but also sensitivity to variations in stimulus category (Herrmann et al., 2005) and configuration (Halit et al., 2000; Itier & Taylor, 2004; Jacques & Rossion, 2007a) or attentional modulations (Rossion et al., 1999a; Taylor, 2002).

Overall, findings from the experiments reported in this thesis provide mixed evidence regarding the influence of ethnicity, expertise, individuation training and task demands on the P1 ERP component.

In the first study on the effect of expertise in the own-race bias, neither ethnicity nor expertise affected P1 latency or amplitude. In line with this, no significant effects of ethnicity on P1 latency were observed in the second experiment on the effect of learning tasks. P1 amplitude, however, appeared to be affected by ethnicity and the learning task, with enhanced P1 amplitudes observed in the categorization group as compared to the attractiveness rating group during learning phases, a finding that may be interpreted as reflecting differences in arousal and attention between experimental groups (Rossion et al., 1999a). In that line, it appears plausible to assume that participants in the categorization group exhibited enhanced spatial attention to race-specific differences in low-level stimulus characteristics. Furthermore, the right-hemispheric P1 was enhanced to Asian faces in learning phases. The finding of ethnicity-dependent variations of P1 amplitude has to be interpreted with caution though, since even slight variations in low-level stimulus characteristics may have elicited this effect (for a related discussion, see Jacques & Rossion, 2006; Jacques, d'Arripe, & Rossion, 2007). Furthermore, analyses of P1 latency and amplitude from the third study on training effects on the own-race bias yielded an ethnicity-dependent latency effect in test phases, with slightly delayed P1 peaks to Asian faces. Finally, the fourth study on the influence of inversion on face and object processing yielded a P1 latency effect, with earlier P1 peaks to houses, and a P1 amplitude effect, with enhanced amplitudes for inverted compared to

upright faces, but not houses. In line with previous findings, the latter effect of increased P1 amplitudes to inverted faces (Itier & Taylor, 2002; Jacques & Rossion, 2007a) may be interpreted as reflecting sensitivity of early perceptual face encoding to inversion, which in turn may bring about differences in local low-level stimulus characteristics (Jacques & Rossion, 2007a). Apart from these findings, no further effects for ethnicity or inversion were observed.

Taken together, the inconsistent findings on the influence of ethnicity on the P1 ERP component may be taken to suggest that even though P1 may reflect differential processing of own- and other-race faces, these effects might be confounded by other processing demands. In that line, task demands may have induced participants in the categorization condition of the second study to allocate attention resources to the detection of visual markers for ethnicity, thereby eliciting ethnicity-dependent modulations of P1 amplitude, whereas participants in the attractiveness rating condition might have adopted other strategies for processing faces during learning phases. On the other hand, the slight delay in P1 peaks to Asian faces in the test phases of the third experiment is not supported by findings from the other studies. Since this latency difference is only weak (ranging from 1-3 ms), this finding should be regarded with caution. Judging from the findings presented in this thesis and other studies, P1 effects of face ethnicity do not appear in a majority of studies and are, if at all, small and marginal. Therefore, future studies seem necessary to resolve the nature and reliability of these effects.

3.2.2 N170

The N170, often described as a correlate of early structural encoding of faces (Bentin & Deouell, 2000; Eimer, 2000c), is arguably the most intensively examined ERP component in the area of face processing. Based on the finding that N170 has been found to be larger to faces as compared to other stimulus categories (Carmel & Bentin, 2002), it has been proposed that N170 may be specifically sensitive to the detection of faces (Bentin & Carmel, 2002). However, observations of a face-like N170 in experts for non-face stimuli (Tanaka & Curran, 2001) or after intensive training on artificial stimuli (Rossion et al., 2002b) argue for a broader interpretation of N170 as a marker for subordinate-level expertise with certain stimuli (Bukach et al., 2006; for a review, see Rossion et al., 2002a). Furthermore, studies examining the neural correlates of the face inversion effect suggested that N170 is sensitive to the configural processing of faces (Latinus & Taylor, 2006). Most interestingly however, the influence of ethnicity on face processing in the N170 time range has not

yet been fully clarified, since findings on the existence and nature of N170 modulations to own- and other-race faces are largely contradictory and inconsistent (Caldara et al., 2004; Halit et al., 2000; Ito & Urland, 2005).

In regard to the impact of ethnicity on N170 latency, the results from the present thesis yielded clear and consistent findings. In all experiments conducted within the scope of this thesis, other-race faces elicited delayed peaks as compared to own-race faces. This latency effect was observed in recognition memory experiments in both learning and test phases and during the presentation of own- and other-race faces in an inversion study using an orientation judgment task. By contrast, a similar effect was absent in a recent study on other-age face processing (Wiese et al., 2008). Accordingly, this finding may be interpreted as a stimulus-dependent effect when processing own- and other-race faces. Since observers usually have most expertise with faces from their own ethnicity and since subordinate-level expertise may affect N170 (Rossion et al., 2002b), these stimulus dependent effects are assumed to be the product of long-term experience in the structural processing of own-race faces. In line with this, the findings from study 1 suggest that expertise with a limited number of other-race individuals acquired over several years does not exert an effect on N170, hence supporting the claim for long-term expertise, as a critical factor in the N170 response to own- and other-race faces.

In contrast, analyses of N170 amplitude yielded more negative N170 peaks to other-race faces in recognition memory experiments only. In relation to the inconsistent findings in the literature, these results of an N170 amplitude effect in tasks requiring participants to explicitly process faces for identity (cf. Stahl et al., 2008; Stahl et al., 2010; Herrmann et al., 2007; Walker et al., 2008) and the absence of similar findings in studies relating to face categorization along perceptual dimensions (Wiese et al., 2009) or visually-derivable social categories (Caldara et al., 2004) argue for a task-dependent amplitude effect in the N170, in that N170 amplitude is sensitive to face ethnicity when participants are required to process identity-related information of own- and other-race faces in recognition memory paradigms.

In previous studies on the effect of picture-plane inversion, N170 has been shown to be delayed to inverted as compared to upright faces (Eimer, 2000a; Itier & Taylor, 2002; Latinus & Taylor, 2006; Rossion et al., 1999b). Since face inversion is assumed to disrupt configural processing of faces (for a review, see Rossion, 2008), N170 has been interpreted to reflect the configural processing of faces, specifically in regard to first-order configurations and holistic information (Latinus & Taylor, 2006). Configural processing is also assumed to be decreased for other-race faces (Rhodes et al., 2006), which may result in inaccurate encoding of other-race faces

and therefore lower recognition memory performance (Walker & Tanaka, 2003). As reported above, upright other-race faces elicit delayed N170 peaks, a finding that might be attributed to decreased configural processing. However, as revealed in study 4, inversion additionally delayed (and enhanced) N170 to own- and other-race faces to a similar extent. Therefore, the effects of ethnicity and inversion on N170 latency were *additive*, with N170 latency increasing incrementally to other-race and inverted faces. Hence, it appears plausible to assume that both inversion and the presentation of other-race faces delayed configural and/or holistic processing to a similar extent, so that configural processing may be assumed to be qualitatively similar for own- and other-race faces, but possibly less efficient for other-race as compared to own-race faces.

Interestingly, ERP data from the recognition memory experiments differs in regard to the lateralization of N170 ethnicity effects in test phases. More precisely, Asian faces elicited increased N170 amplitudes over the left hemisphere in study 1 (influence of expertise), whereas the same effects were visible over the right hemisphere in study 2 (learning task effects) and 3 (effect of individuation training). Intriguingly, in a study on the influence of featural and configural changes in faces (Scott & Nelson, 2006), the left-hemispheric N170 was observed to be particularly sensitive to featural changes in faces, whereas the right-hemispheric N170 appeared to be sensitive to configural changes, an assumption also supported by findings of enhanced activity in the right fusiform gyrus after expertise training with novel stimuli (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Gauthier & Tarr, 2002). Whereas the functional significance of the observed lateralization effects cannot be explained by the present data, future studies appear necessary to further specify the possible interaction of experimental design and lateralization of N170 amplitude effects in regard to featural and configural processing of own- and other-race faces.

Apart from the findings described in the previous paragraphs, N170 was also affected by individuation training, in that earlier N170 peaks were recorded to own- and other-race faces after training. In line with earlier N170 peaks observed in a previous study on the effects of individuation training (Tanaka & Pierce, 2009), these findings may reflect a facilitatory effect of training on the N170 and therefore argue for more efficient structural encoding after individuation training for own- and other-race faces. Future studies on training effects on N170 latency should further examine the task specificity of this effect, since findings from the present thesis are not sufficient to resolve this question.

Taken together, the findings from this thesis provide support for the assumption that N170 is affected by face ethnicity, inversion and the underlying differences in

processing objectives when participants are required to either process faces for identity (recognition tests) or to categorize faces along different social categories without making identity judgments. Furthermore, perceptual training may facilitate structural encoding and elicit more efficient face processing in the N170 time range as seen by N170 latency decreases after training.

3.2.3 P2

The P2 ERP component has been reported to be sensitive to configural manipulations in faces (Boutsen, Humphreys, Praamstra, & Warbrick, 2006) and has been further assumed to be involved in the processing of second-order configurations in individual faces (Latinus & Taylor, 2006). The P2 in face processing has therefore been linked to the initiation of individual recognition mechanisms (Halit et al., 2000). Of particular importance to the present thesis on the effects of ethnicity on face recognition, P2 has also been found to be increased to young as compared to old faces in young participants (Wiese et al., 2008), and may reflect the expertise to extract those facial information critical for the discrimination of individual faces (Mercure et al., 2008).

In general, findings from recognition memory experiments reported in this thesis demonstrate enhanced P2 amplitudes to own-race faces. Of particular importance and in contrast to present findings on the N170, these P2 ethnicity effects were susceptible to modulations by experimental factors such as expertise with other-race faces (study 1), learning task demands (study 2) and individuation training (study 3). More precisely, in study 1, own-race faces elicited enhanced P2 amplitudes over both hemispheres in the control group, whereas this effect was absent over the right hemisphere in the expert groups. Similarly in study 2, enhanced P2 amplitudes to own-race faces were evident over both hemispheres in the categorization group, but the effect was abolished over the left hemisphere in the attractiveness rating group. Finally, as observed in study 3, individuation training eliminated an initially bilateral P2 amplitude effect over the left hemisphere. Earlier findings on ERP correlates of face learning and recognition showed a P2 amplitude decrease as a result of perceptual learning, which has been linked to second-order configural processing of faces (Latinus & Taylor, 2005). More importantly, greater P2 amplitudes to normal as compared to spatially distorted (Halit et al., 2000) and to typical as compared to Thatcherized faces (Milivojevic et al., 2003) were assumed to reflect configural processing, specifically over the right hemisphere (Milivojevic et al., 2003). In the studies reported here, only participants with expertise with other-race faces (study 1)

exhibited a lower own-race bias, which may be the result of relatively more accurate configural processing of other-race faces as compared to non-expert controls and therefore better recognition performance.

Intriguingly, these participants exhibited no *right*-hemispheric amplitude differences in P2 to own- and other-race faces. In contrast to this, the abolished P2 amplitude differences between own- and other-race faces over the *left* hemisphere in the non-expert participants in study 2 and 3 were not accompanied by a decrease in the behavioral own-race bias. Since particularly the right-hemispheric P2 has been shown to be sensitive for the processing of configural information in faces (Milivojevic et al., 2003), the absence of right-hemispheric differences in P2 amplitudes to own- and other-race faces in experts (study 1) argues for more similar configural processing of own- and other-race faces. Moreover, it has been demonstrated that the accurate encoding of second-order configural information is particularly critical for the discrimination and correct recognition of individual faces (Diamond & Carey, 1986; Rotshtein, Geng, Driver, & Dolan, 2007). In line with this, the own-race bias has been explained to result from an experience-driven fine-tuning of face processing mechanisms to faces of one's own ethnicity, which in turn has been suggested to cause discrepancies in recognition memory accuracy to own- and other-race faces (Hancock & Rhodes, 2008; Rhodes et al., 2009). Taking into account that experts in study 1 indeed exhibited improved recognition accuracy to other-race faces as compared to non-experts (Stahl et al., 2008; Stahl et al., 2010), the behavioral findings and the *absence* of an ethnicity-dependent right-hemispheric P2 effect argue for the interpretation that particularly the right-hemispheric P2 may be a marker for expert-like processing of second-order configural information and improved recognition of other-race faces.

Taken together, these findings suggest that right-hemispheric configural processing of other-race faces may be a necessary precondition for improved other-race face recognition. In line with this, comparable configural processing of own- and other-race faces as observed in left-hemispheric P2 ethnicity effects were not sufficient in inducing behavioral improvements in recognition accuracy to other-race faces, which may be due to participants' inability to adequately store other-race faces in memory. In contrast, own-race face processing was impaired in study 3, resulting in lower discrimination accuracy to own-race faces and in turn a lower own-race bias. The latter findings may result from a training-induced change in the configural processing of own- and other-race faces. I assume that participants in study 3 learned to shift their attention to discriminate between other-race faces (as reflected in a modified response bias to other-race faces after training), which may have been at the cost of encoding relevant information for the discrimination of own-race faces. In

that line, it could be hypothesized that P2 is affected by top-down modulations of perceptual processing and that P2 effects may reflect attentional shifts in the processing of configural information in own- and other-race faces.

In sum, P2 has been shown to be influenced by face ethnicity, with own-race faces eliciting generally increased P2 mean amplitudes. Importantly, the P2 ethnicity effect is modulated by factors assumed to affect processing of own- and other-race faces, namely expertise with other-race faces (study 1), individuation training for own- and other-race faces (study 3) and learning task demands in recognition memory paradigms (study 2). In line with the assumption that expertise is generally associated with increased use and better encoding of configural information in faces, right-hemispheric P2 effects of comparable processing of own- and other-race faces may be interpreted as a marker for expert-like second-order configural processing of other-race faces.

3.2.4 N250

Previous findings on the effects of face ethnicity on processing in the N250-time range reported no effects of repetition for own- and other-race faces in the N250r (Herrmann et al., 2007), but an effect of training, with increased N250 amplitudes as a result from other-race individuation training, but not after categorization training (Tanaka & Pierce, 2009). Within the scope of the present thesis, only one study included analysis of the N250 component. In learning phases of pre- and post-training recognition memory experiments of the individuation training study (study 3), Asian faces elicited more negative N250 amplitudes as compared to Caucasian faces over both hemispheres, with larger ethnicity-dependent amplitude differences observed over the left hemisphere. In test phases, training differentially affected N250 amplitudes to own- and other-race faces, thereby eliciting significantly more negative mean amplitudes to Asian faces in the pre-training test, but no such N250 effects in the post-training test. Furthermore, a trend for an interaction of hemisphere x face ethnicity indicated numerically greater ethnicity-dependent amplitude effects over the right hemisphere. In addition, increased N250 amplitudes to hits as compared to CRs over the left hemisphere as observed in the pre-training recognition memory experiment were absent after training, which may be suggested to reflect training-induced changes in the access to temporary structural representations of studied faces (cf. Schweinberger & Burton, 2003). Taken together, the present findings on ethnicity-dependent N250 effects appear somewhat similar to the P2 findings on differential processing of own- and other-race faces starting at

approximately 220-230 ms after stimulus onset. Just by visual inspection of the waveforms, one could cautiously argue that the P2 and N250 components may in fact be representations of different processes co-occurring within the same functional complex and time range. In that line, the occipito-temporal P2 component could be interpreted as representing an early part of the N250 difference wave, a hypothesis that needs to be clarified within the scope of future studies on own- and other-race face processing.

3.2.5 LPC and the old/new-effect

Whereas analyses of the above mentioned ERP components was carried out in all studies in the scope of this thesis, due to methodological issues, analyses of the LPC and old/new-effect were only reported for study 2 and 3.

Whereas examination of own- and other-race face processing in the learning phases in study 3 showed generally larger LPC amplitudes to other-race faces in both pre- and post-training tests, findings from study 2 showed a significant influence of the learning task on this effect. This was reflected by larger LPC amplitudes to other-race faces over posterior electrodes in the categorization group, but no LPC differences between own- and other-race faces in the attractiveness rating group. Given that larger LPC amplitudes may reflect greater violation to the mechanisms for analyzing configural information in faces (Bobes et al., 1994) and that increased amplitudes to other-race faces were suggested to reflect greater allocation of processing resources to more novel faces (James et al., 2001), the finding of an abolished difference in the LPC to own- and other-race faces in study 2 may be regarded as a correlate of similar mechanisms in late stages of face processing and encoding. However, despite comparable processing in the LPC time range, participants in the attractiveness rating group did not exhibit a reduced own-race bias. Contrary to explanations of the own-race bias as an encoding-based effect (cf. Meissner et al., 2005), participants' inability to benefit from relatively better encoding of other-race faces argues for retention or retrieval problems as the cause of the own-race bias (Papesh & Goldinger, 2009).

Finally, comparison of the old/new-effect (greater mean amplitudes to learned as compared to new faces) for systematical effects of face ethnicity or an influence of training or task modulations yielded mixed findings. Whereas a basic old/new-effect was found in study 2 and 3, this effect was modulated by ethnicity and learning task in study 2. Here, the old/new-effect in the attractiveness rating condition was more pronounced to own-race faces as compared to other-race faces. At the same time, no

comparable effect of ethnicity on the old/new-effect was observed in the categorization group. It has been shown that the parietal old/new-effect is sensitive to the amount of information recollected from episodic memory (Vilberg et al., 2006). Furthermore, it has been suggested that participants recollect more detailed information about own-race faces as compared to other-race faces (Meissner et al., 2005). Accordingly, the greater old/new-effect for own-race faces in participants from the attractiveness rating group (study 2) may argue for a larger amount of recollected information for correctly recalled own-race faces in participants under the attractiveness rating condition. On the contrary, it appears that participants may not have been able to benefit from presumably better encoding of other-race faces in learning phases (as reflected in more similar processing of own- and other-race faces in the LPC). In contrast, findings from study 3 suggest an effect of individuation training on the old/new effect, arguing for similar processing of own- and other-race faces during retrieval from memory. At the same time, training has not been observed to exert an effect on encoding processes, as seen in ethnicity-dependent amplitude differences in the LPC in learning phases.

Taken together, the present findings demonstrated top-down modulations by task demands and individuation training on later stages of face processing. Whereas a change in task demands abolished amplitude differences in the encoding of own- and other-race faces as reflected in the LPC in learning phases, individuation training affected the old/new effect, thereby arguing for similar retrieval processes for own- and other-race faces in test phases of recognition memory experiments. Importantly, neither of these effects was paralleled by enhanced recognition performance to other-race faces. Previous studies have argued that the own-race bias may be caused by inferior encoding (Meissner et al., 2005) or retrieval (Papesh & Goldinger, 2009) of other-race faces. However, the present findings suggest that neither enhanced *encoding* (study 2) nor improved *retrieval* processes (study 3) for other-race faces *alone* significantly affect the behavioral own-race bias. It could therefore be assumed that the own-race bias is due to retention problems, which contradicts socio-cognitive accounts of the own-race bias assuming an effect of strategic changes in own- and other-race face processing on the own-race bias. In contrast, the present findings are in line with expertise-based accounts of the own-race bias, which propose better representation and storage of own-race faces in memory as a result of perceptual expertise acquired over the lifetime.

3.3 Conclusion

Within the scope of the present thesis, determinants of both the behavioral own-race bias as well as ERP correlates of own- and other-race face processing were examined.

On the behavioral level, the own-race bias appears to be a very stable phenomenon, the magnitude of which was only slightly reduced by perceptual expertise with other-race faces acquired through individuating contact over a longer period of time (study 1) or by individuation training on own- and other-race faces (study 3), but not by learning task modulations (study 2). These findings support expertise-based accounts of the own-race bias, which propose the existence of an experience-driven memory system that is fine-tuned to the optimal representation and recognition of own-race faces (Valentine, 1991; Valentine & Endo, 1992). Furthermore and as documented in this thesis, intensive contact with other-race individuals may help to alleviate the own-race bias in participants with expertise (study 1), arguing for the capacity of face space to adapt through perceptual experiences gathered over several years, even in the case of limited contact with a smaller number of other-race individuals. Additionally, the own-race bias was also reduced in participants who underwent individuation training on own- and other-race faces. However, contrary to expectations from an expertise-based perspective, this decrement in the post-training own-race bias was not due to enhanced recognition performance to other-race faces, but to a training-induced decrement in recognition accuracy to own-race faces.

Similarly to behavioral variables, neural correlates of face processing were affected by ethnicity, individuation and expertise with other-race faces. Moreover though, and incongruent with their impact on the behavioral own-race bias and other-race face recognition performance, learning task demands and training exerted an influence on ERP correlates of own- and other-race face processing (see Fig. 3 for schematic model of determinants of own- and other-race face processing).

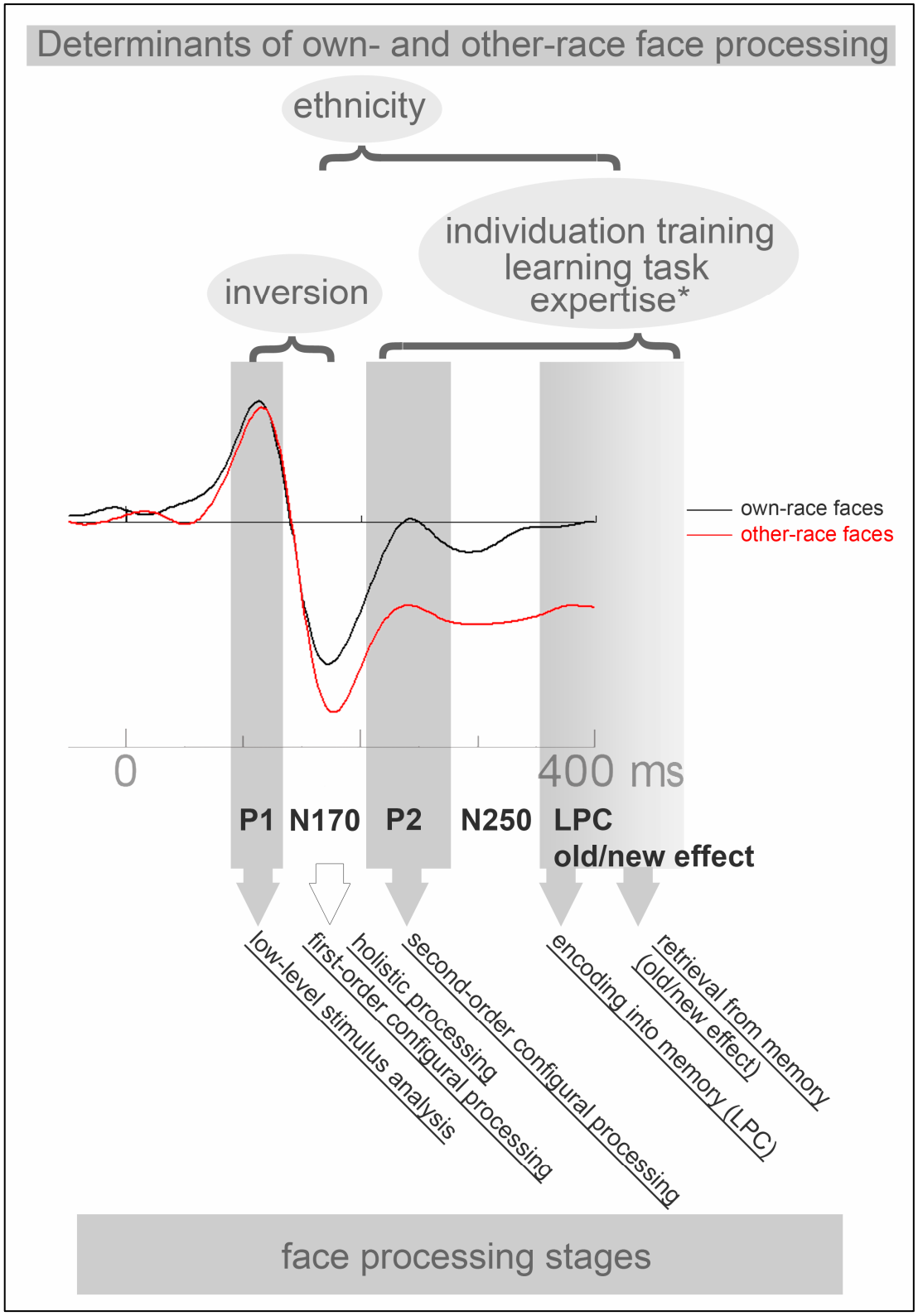

Figure 3: An integrative model of the functional relevance of different processing stages and ERPs for the processing of own- and other-race faces: this model offers a schematic overview of the influence of different factors on the processing of own- and other-race faces within the scope of the different face processing stages as suggested by Bruce and Young (1986). Whereas findings from the present thesis support the majority of the assumptions presented above, the effects of expertise on late stages of face processing as seen in the LPC and old/new effect have not been determined yet and need to be examined through further studies on the impact of various factors on own- and other-race face processing.

Generally, decreased N170 amplitudes for own-race as compared to other-race faces were observed across studies, while the P2 ethnicity effects in recognition memory experiments were differentially modified by expertise with other-race faces on the one hand and the impact of training and task demands on the other hand. Accordingly, the absence of a right-hemispheric P2 ethnicity effect was paralleled by an actual decrease in the own-race bias in experts (study 1). In contrast, the absence of left-hemispheric P2 effects (as observed in studies 2 and 3) did not induce better recognition memory of other-race faces. Importantly and in regard to theories assuming qualitative differences in configural processing of own- and other-race faces as the basis of the own-race bias, it has been shown that the effects of ethnicity and inversion on N170 latency (study 4) were additive, which argues for similar quality of the processing of configural information in own- and other-race faces, but presumably less efficient processing of other-race as compared to own-race faces. Moreover, the present findings of comparable, though less efficient configural processing of own- and other-race faces in the N170 time range do not necessarily contradict differential processing accounts of the own-race bias. More specifically, the subsequent P2 component has been suggested to be sensitive to the processing of second-order configural information in own- and other-race faces and may be assumed to be a marker for ethnicity-dependent processing differences that underlie the own-race bias.

The outcomes of this thesis therefore argue for i) a stable pattern of the effects of long-term expertise with own-race faces on the N170 and ii) an influence of situational factors and top-down processing on neural correlates of configural face processing as evidenced in the P2 ERP correlate. However, iii) these situational effects were not paralleled by behavioral improvements in recognition accuracy for other-race faces in participants lacking intensive long-term experience with other-race individuals and could be taken to suggest problems of adequately storing other-race faces in memory as the underlying cause of the own-race bias. Finally, iv) the absence of right-hemispheric P2 amplitude differences between own- and other-race faces is assumed to be a possible marker for expert-like second-order configural processing and improved recognition accuracy to other-race faces. The findings presented in this thesis are therefore in line with theories stressing perceptual expertise and individuating contact as a crucial factor in modulating own- and other-race face processing and alleviating the own-race bias in face perception.

Zusammenfassung

Name: Johanna Stahl
Titel der Dissertation: “Determinants of the Own-Race Bias and neural correlates of own- and other-race face processing”

Die Fähigkeit, Personen anhand ihres Gesichts zu erkennen, ist für unser Sozialleben von großer Bedeutung. Dabei zeigen Menschen jedoch generell bessere Wiedererkennungsleistungen für Gesichter ihrer eigenen Ethnizität verglichen mit Gesichtern einer anderen ethnischen Gruppe. Diese als Own-Race Bias beschriebene Diskrepanz in der Rekognition von Gesichtern der eigenen und einer fremden Ethnizität beruht vermutlich auf Expertise, die über die Lebensspanne erworben wurde. Diese perzeptuelle Expertise wirkt sich wiederum auf die Qualität der Kodierung von individuellen Merkmalen in Gesichtern aus.

Ziel der vorliegenden Dissertation war es, Einflussfaktoren auf den Own-Race Bias zu analysieren und zu untersuchen, ob und wenn ja, in welchem Ausmaß, der Own-Race Bias durch Expertise mit Gesichtern einer anderen Ethnizität, unterschiedliche Aufgabenstellungen beim Einprägen von Gesichtern oder durch intensives Rekognitionstraining gesenkt werden kann. In den Experimenten zur Untersuchung der Gedächtnisleistung der Probanden wurde jedoch nicht nur Own-Race Bias anhand von Wiedererkennungsleistungen gemessen, sondern ebenfalls die elektrische Hirnaktivität mittels EEG abgeleitet und anhand von ereigniskorrelierten Potentialen (EKPs) ausgewertet. Diese Methode erlaubt es, in Echtzeit den Zeitverlauf neuronaler Aktivierungsmuster abzubilden und auch solche neurokognitiven Verarbeitungsmuster aufzudecken, die sich in den Verhaltensdaten nicht direkt beobachten lassen.

Die Befunde aus dieser Dissertation legen nahe, dass es sich bei dem Own-Race Bias um einen sehr stabilen Effekt handelt, welcher nur durch langfristige Expertise mit Menschen einer anderen Ethnizität signifikant gesenkt werden kann. Gleichzeitig konnte gezeigt werden, dass Unterschiede in der Verarbeitung von Gesichtern der eigenen und einer anderen Ethnizität schon in sehr frühen Stufen der neurokognitiven Verarbeitung auftreten. Während über mehrere Studien hinweg generell niedrigere Amplituden in der EKP-Komponente N170 für Gesichter der eigenen Ethnizität beobachtet wurden, gab es differentielle Einflüsse auf die Lateralisierung von Ethnizitätsunterschieden in der darauffolgenden EKP-Komponente P2. So führte

Expertise mit Gesichtern einer anderen Ethnizität dazu, dass signifikant positivere P2-Amplituden für Gesichter der eigenen Ethnizität nur noch über der linken Hemisphäre zu beobachten waren, wohingegen Rekognitionstraining und die Änderung der Lernaufgabe einen vergleichbaren Effekt über der rechten Hemisphäre verursachten. Die beiden letztgenannten Faktoren hatten jedoch - im Gegensatz zu langfristig erworbener Expertise mit Gesichtern einer anderen Ethnizität – keinen Einfluss auf den behavioralen Own-Race Bias und führten somit nicht zu besseren Erkennungsleistungen für Gesichter einer anderen Ethnizität. Diese Befunde sind daher im Einklang mit Theorien, die den Own-Race Bias vorrangig auf perzeptuelle Expertise zurückführen und intensiven Kontakt mit Individuen einer anderen Ethnizität als kritischen Faktor für die Senkung des Own-Race Bias ansehen.

List of abbreviations

CR	correct rejection
EEG	electroencephalogram
ERP	event-related potential
FA	false alarm
FIE	face inversion effect
LH	left hemisphere
LPC	late positive complex
MDFS	multi-dimensional face space
RH	right hemisphere
ROI	region of interest
RT	reaction time

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Appendix

This chapter contains the articles and the manuscript presented and discussed within the present thesis in the following order:

Study 1: Expertise and the own-race bias: an event-related potential study (Stahl et al., 2008)

Study 2: Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance (Stahl et al., 2010)

Study 3: The effect of individuation training on recognition performance and ERP-correlates of the own-race bias (Stahl et al.submitted)

Study 4: Configural processing of other-race faces is delayed but not decreased (Wiese et al., 2009)

Expertise and own-race bias in face processing: an event-related potential study

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Humans remember own-race faces more accurately than other-race faces (own-race bias). This effect is reduced by expertise with other-race faces. This study examined event-related potentials to own-race and other-race faces in a group of experts to other-race faces and a nonexpert control group. Both groups exhibited own-race recognition biases. Other-race faces elicited more negative and delayed N170 components, suggesting enhanced configural processing of own-race compared with other-race faces. Moreover, an increased P2 (approximately 210–240 ms) was observed for own-race faces. At right occipitotemporal regions of the experts only this P2 effect was found to be absent. These findings demonstrate an influence of early, presumably presemantic processes on the own-race bias, which are mediated by perceptual expertise with other-race faces. *NeuroReport* 19:583–587 © 2008 Wolters Kluwer Health | Lippincott Williams & Wilkins.

Keywords: event-related brain potentials, expertise, face, own-race bias

Introduction

Faces from the observers' ethnic group are recognized better than faces from other ethnicities, an effect known as the own-race bias [1–4]. Various theories have been put forward to account for this phenomenon. Although approaches from social cognition stress a role of racial stereotypes [5], research from the area of face processing suggests differential visual processing as the basis of the own-race bias, with configural processing playing a more important role than feature-based processing in the case of own-race faces and the reverse trend in the case of other-race faces [6]. Moreover, the face-space model by Valentine and Endo [1] suggests better coding of own-race faces along multiple dimensions, resulting from an observer's lifetime experience with faces. In line with this, the own-race bias is weakened by expertise with other-race faces [2,3].

Given their high temporal resolution, event-related potentials (ERPs) offer an excellent tool to investigate early perceptual processes when presenting participants with own-race and other-race faces. The ERP component in face perception research that received most scientific attention is the N170, a negative deflection maximal at right occipitotemporal sites [7], which has been interpreted to reflect the structural encoding of faces [8]. The N170 has been found to be larger for atypical compared with typical faces [9]. As other-race faces may be more atypical [1], they should elicit larger N170 components. A larger and delayed N170 was also reported for inverted compared with upright faces [10], an effect thought to reflect the disruption of configural processing, which in turn was described as being more important for the coding of own-race faces [11]. Hence, N170 to other-race faces should be larger compared with own-race faces. The N170, however, is also increased by expertise [12], therefore predicting a larger N170 to own-race faces. Accordingly, two ERP studies reported larger N170 responses for own-race in comparison to other-race faces [13,14]. In contrast, and in line with the first argument, a recent study observed a larger N170 for other-race faces [15]. Finally, several studies did not detect N170 differences [16,17]. Hence, the mechanisms by which the N170 may be modulated by face ethnicity remain unclear.

None of the previous ERP studies directly investigated expertise effects on ERP correlates of own-race versus other-race face processing. Moreover, previous studies largely restricted their analyses to the N170 component. Accordingly, it is still unknown whether expertise influences early perceptual processes reflected in N170 or subsequent ERP components. Of particular interest, a study by Halit and coworkers [9] demonstrated larger right posterior P2 responses (approximately 188–300 ms) to typical as compared with atypical faces, the configuration of which had been altered by spatial distortion. In this study we aimed at adding further evidence to open questions outlined above by examining P1, N170 and P2 ERP correlates of the own-race bias in a group of other-race face experts and controls.

Methods

Participants

Forty right-handed participants contributed data. A control group (N=20, M=22.3 years, 17 females) without considerable experience regarding Asian people and an expert group (N=20, M=27.2 years, nine females) with intensive experiences regarding Asian faces (at least 3 years of intensive interaction with Asian individuals) were tested. All participants gave informed written consent and the

study was conducted in accordance with the Declaration of Helsinki.

Stimuli

Stimuli were black and white photographs of 120 unfamiliar Asian and 120 unfamiliar Caucasian faces (50% female). Photographs were taken from the CAL/PAL face database [18] and other web-based databases. Stimuli were front-view faces without strong expression, presented centrally with a size of $3.8 \times 4.8^{\circ}$ visual angle at a viewing distance of approximately 90 cm, kept constant by a chin rest.

Procedure

After a short practice block, the experiment consisted of six blocks (60 trials each), each divided into a 'learning phase' (20 trials) and a subsequent 'test phase' (40 trials). During each trial of the learning phase a fixation cross was initially presented for 500 ms, followed by a stimulus image for 5000 ms. Half of the stimuli were Asian and Caucasian faces, respectively (each with 50% female faces). Participants made speeded ethnicity judgments via button presses using their left and right index fingers, and had to memorize each face. Stimulus onset asynchrony was 6000 ms.

In the test phases, participants made speeded old/new judgments. Half of the stimuli were included in the directly preceding learning phase, whereas the other half comprised new stimuli. During each trial of the test phase, a fixation cross (500 ms) was followed by a test face for 2000 ms. Stimulus onset asynchrony was 3000 ms. Forty trials were presented in pseudo-randomized order in each of the six test phases (20 trials for old faces and 20 new faces), with the restriction that at least five other faces were presented between the same face in the learning and subsequent test phase (cf. Fig. 1).

Apparatus

EEG was recorded using a 144 channel Biosemi Active II system (BioSemi, Amsterdam, The Netherlands). Electrode positions included 128 standard Biosemi sites plus 16 inferior temporal, occipitotemporal and occipital sites. EEG (DC to 75 Hz) was sampled at 256 Hz. Trials with artefacts or incorrect behavioural responses were rejected. Ocular contributions to the EEG were corrected [19]. ERP epochs to test faces were calculated for 1400 ms (200 ms prestimulus baseline). ERPs were recalculated to average reference and digitally low-pass filtered at 20 Hz (zero phase shift).

Data analysis

Data from the test phases were sorted into four conditions for Asian and Caucasian faces: hits (correctly identified old faces), misses (old faces classified as new), correct rejections (CR, correctly classified new faces) and false alarms (FA, new faces classified as old). Sensitivity (d′) and response bias (C) measures were determined.

For statistical analysis, ERPs were pooled within 16 regions of interest (ROIs). ROIs were frontal medial, frontal right/left, central medial/right/left, central left/right inferior, parietal medial/right/left, frontotemporal right/left, occipitotemporal right/left (OTR, OTL) and occipital medial (OM). As face-sensitive components are most prominent at occipitotemporal regions [7], only OTR and OTL were analysed for the ERP components N170 and P2. The P1 component was analysed at OM. For ERPs in the test phases, mean amplitudes were calculated from 100 to 120 ms (P1), from 150 to 170 ms (N170) and from 210 to 240 ms (P2). Peak latencies for the P1 and N170 components were determined at OM and OTR, respectively.

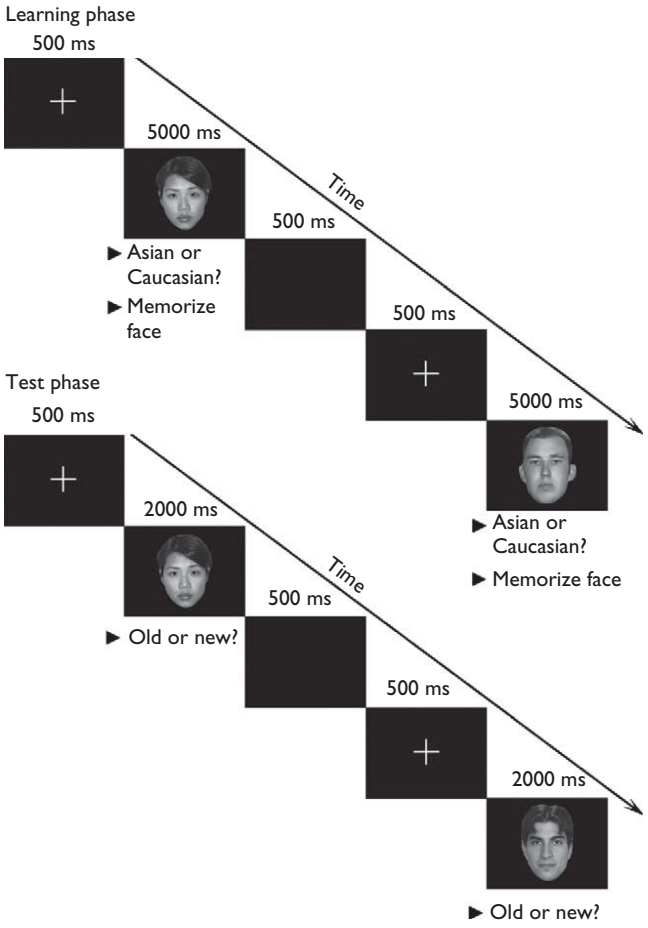

Fig. 1 Top: Course of learning phase. During stimulus presentation participants were required to (i) categorize faces according to their ethnicity, and (ii) memorize each face. Bottom: Corresponding stimuli from the test phase, showing an old face from the directly preceding learning phase and a new face. Participants were required to make speeded old/new judgments.

Statistical analysis involved mixed-model and repeated-measures analyses of variance (ANOVAs) as well as post-hoc *t*-tests. All post-hoc tests were corrected for multiple comparisons using the Bonferroni procedure.

Performance

An ANOVA for sensitivity (d′) yielded main effects for 'face ethnicity' [$F(1,38)=57.64$, $P<0.001$] and 'group' [$F(1,38)=4.66$, $P<0.05$], but no interaction of these factors [$F(1,38)=1.68$, $P=0.202$]. Hence, higher sensitivities were measured for Caucasian faces compared with Asian faces, and for experts compared with controls. An ANOVA for response criterion (C) yielded a main effect for 'face ethnicity' [$F(1,38)=12.86$, $P<0.001$], indicating a less conservative response bias for Asian compared with Caucasian faces (cf. Table 1).

Table 1 Performance data from the test phases

Group	Control group		Expert group	
Face ethnicity	Caucasian	Asian	Caucasian	Asian
d′				
M	1.87	1.29	2.10	1.69
SD	0.57	0.46	0.54	0.46
C				
M	0.26	0.14	0.34	0.08
SD	0.31	0.29	0.34	0.35

C, response criterion; d′, sensitivity.

Event-related potential results

An analysis of P1 amplitude at OM with the between-subject factor 'group' and the within-subject factors 'face ethnicity' and 'response' (hits/correct rejections) yielded no effects or interactions involving face ethnicity or response ($P > 0.05$). Mean P1 peak latency at OM was 110.6 ms, with no differences between Caucasian (M=110.6±8.2 ms) and Asian faces (M=110.5±7.4 ms) (Fig. 2).

Analysis of N170 amplitude at OTL revealed main effects for 'face ethnicity' [F(1,38)=5.48, $P < 0.05$], with more negative amplitudes for Asian faces, and 'response' [F(1,38)=14.92, $P < 0.001$], with more negative amplitudes for old faces. No significant interaction of these factors [F(1,38)=0.12, $P > 0.05$] was observed. No such effects were found for N170 amplitude at OTR. Furthermore, an ANOVA

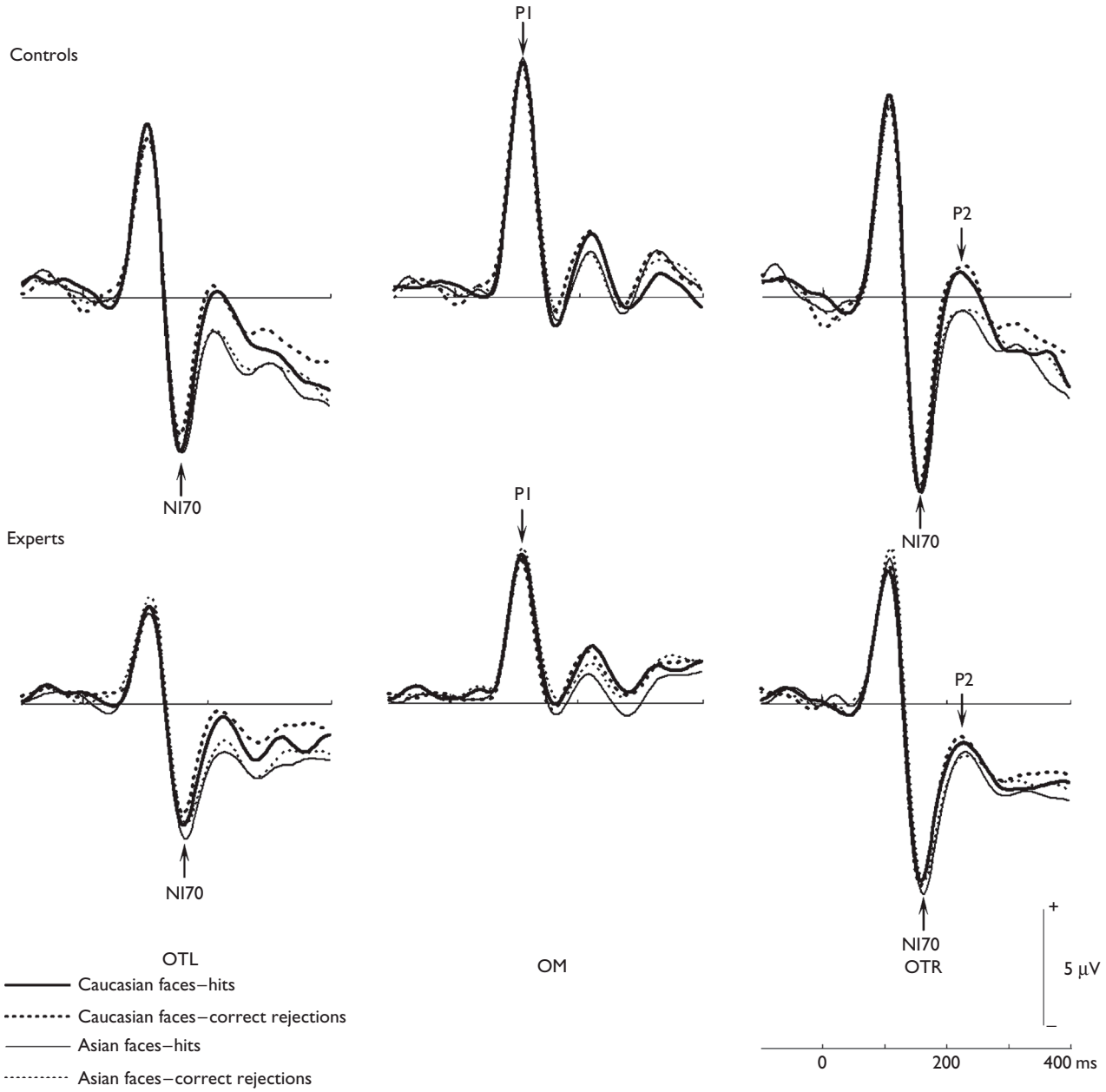

Fig. 2 Grand average event-related potentials (ERPs) for middle, left and right occipitotemporal regions of interest (ROIs) [occipital medial (OM), occipitotemporal left (OTL) and occipitotemporal right (OTR)], displayed separately for control and expert group. Note the P2 ERP main effect for face ethnicity in the control group in ROI OTR, which was absent in the expert group.

of N170 latency at OTR yielded a main effect for 'face ethnicity' [$F(1,38)=15.91$, $P<0.001$], indicating earlier peaks for Caucasian faces ($M=157.3\pm1.5$ ms) compared with Asian faces ($M=160.5\pm1.6$ ms).

P2 amplitude at OTL showed a main effect for 'face ethnicity' [$F(1,38)=57.02$, $P<0.001$], with less positive amplitudes for Asian faces. At OTR, a main effect for 'face ethnicity' [$F(1,38)=20.68$, $P<0.001$] was qualified by an interaction 'face ethnicity × group' [$F(1,38)=4.46$, $P<0.05$]. Subsequent post-hoc *t*-tests showed that this interaction reflected less positive amplitudes for Asian compared with Caucasian faces in the control group [$t(19)=4.23$, $P<0.001$], whereas no such differences were found in the expert group [$t(19)=1.96$, $P>0.05$].

Discussion

This study observed evidence for differential neural processing of own-race versus other-race faces. Caucasian participants with and without expertise for Asian faces demonstrated a clear own-race bias in performance. Although more negative amplitudes for other-race faces were observed in the N170 time range in both groups, the subsequent P2 response (approximately 210–240 ms) was modulated by expertise. Although a less positive P2 response to other-race faces was clearly present for controls, a corresponding effect in the right occipitotemporal P2 response was not observed in experts.

As demonstrated by Tanaka and colleagues [6], own-race faces are typically processed holistically (and more configurally) whereas other-race faces undergo featural processing to a greater extent. The present results on the N170 response may be in line with previous findings that demonstrate longer latencies and increased amplitudes of this component with disturbed configural processing of faces [12]. Although earlier studies did not detect occipitotemporal N170 effects for own-race versus other-race faces [13,17], a recent study reported similar results [15]. The precise reason for these discrepant findings is unclear as yet, but we note that a common feature of that study and the present one is that both used tasks that explicitly required processing of faces for identity. Furthermore, the finding of greater differences in N170 amplitude over the left hemisphere is in line with the hypothesis that the left-hemispheric N170 seems to be particularly sensitive to featural changes in faces as opposed to configural changes [20].

Of particular importance, an expertise-dependent face ethnicity effect was detected in the subsequent occipitotemporal P2 component. A larger P2 for typical compared with atypical faces has been reported in an earlier study [9] where the engagement of individual recognition mechanisms was suggested to cause this effect. Similarly, an enhanced P2 response for photographic as compared with Mooney faces was reported previously [21], and linked to second-order configural processing. The present results extend previous findings by demonstrating differential processing of own-race and other-race faces in the P2. Importantly, however, the present P2 effect was modulated by expertise, and experts (but not controls) demonstrated comparable P2 responses to own and other-race faces over the right hemisphere, probably reflecting the recruitment of similar recognition mechanisms for other-race faces in experts.

Although expertise affected the P2 in this study, previous studies reported effects of expertise on the N170 [22,23]. In these studies expertise was examined with either different classes of stimuli (e.g. dog and bird experts were tested with pictures of dogs and birds), or trained and preexperimentally unknown artificial stimuli ('Greebles'). This study did not detect expertise effects in the N170. (i) However, the comparison of two subcategories within one broad stimulus class in this study, namely Asian and Caucasian faces, and (ii) the more naturalistic definition of expertise (real-life experience with other-race faces versus experimentally induced training) may complicate a direct comparison of those studies with the present results. More recently, and potentially related to the present findings, further evidence has been presented suggesting that an ERP response subsequent to the N170 (approximately 230–330 ms) is specifically sensitive to subordinate-level expertise with individual exemplars [24].

Conclusion

In line with earlier studies, the present ERP findings demonstrate a modulation of the N170 component by face ethnicity, arguing for more configural processing of own-race in comparison to other-race faces. Importantly, a subsequent effect of face ethnicity on the P2 response over right occipitotemporal regions was abolished in experts with Asian faces. These results demonstrate an influence of early perceptual processes on the own race bias.

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Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance☆

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ABSTRACT

People are generally better in recognizing faces from their own ethnic group as opposed to faces from another ethnic group, a finding which has been interpreted in the context of two opposing theories. Whereas perceptual expertise theories stress the role of long-term experience with one's own ethnic group, race feature theories assume that the processing of an other-race-defining feature triggers inferior coding and recognition of faces. The present study tested these hypotheses by manipulating the learning task in a recognition memory test. At learning, one group of participants categorized faces according to ethnicity, whereas another group rated facial attractiveness. Subsequent recognition tests indicated clear and similar own-race biases for both groups. However, ERPs from learning and test phases demonstrated an influence of learning task on neurophysiological processing of own- and other-race faces. While both groups exhibited larger N170 responses to Asian as compared to Caucasian faces, task-dependent differences were seen in a subsequent P2 ERP component. Whereas the P2 was more pronounced for Caucasian faces in the categorization group, this difference was absent in the attractiveness rating group. The learning task thus influences early face encoding. Moreover, comparison with recent research suggests that this attractiveness rating task influences the processes reflected in the P2 in a similar manner as perceptual expertise for other-race faces does. By contrast, the behavioural own-race bias suggests that long-term expertise is required to increase other-race face recognition and hence attenuate the own-race bias.

1. Introduction

Faces of another ethnicity are considerably harder to recognize than faces from one's own ethnic group (Brigham & Barkowitz, 1978). This effect, known as own-race bias, is a well-documented phenomenon in the area of face recognition (Meissner & Brigham, 2001). Despite this own-race advantage in *recognition*, there is typically a disadvantage for own-race faces in tasks of ethnicity *classification*, meaning that own-race faces are usually classified more slowly as belonging to a certain ethnicity than other-race faces (Valentine & Endo, 1992). Several theories have been put forward to account for this effect.

1.1. Theoretical approaches

The relevant models and theories can be divided into two broad groups. Whereas several theories suggest perceptual learning and lifetime expertise with faces as the basis of the own-race bias, other models expect socio-cognitive processes and situational contexts to cause the own-race bias.

A prominent example for the former group of models is the multidimensional face-space (MDFS) model by Valentine (1991). It suggests better coding of own-race faces along multiple perceptual dimensions which evolve due to a person's lifetime experience with faces. These dimensions forming the MDFS develop such as to optimally discriminate between individual faces. Since most people acquire face expertise in ethnically homogenous environments, their MDFS relies on dimensions that best serve to discriminate between faces from the individual's own ethnic group. Therefore, experience primarily with one ethnicity of faces results in a MDFS that is specialized towards that specific ethnic group, and therefore less well suited to adequately encode faces from another ethnicity, entailing higher misidentification rates and hence lower recognition accuracy for other-race faces compared to own-race faces (Valentine & Endo, 1992). The perceptual expertise approach gained empirical evidence from three lines of research. These were able to demonstrate that (1) this specialization of the MDFS is a lifelong developmental process and correlates with an increase in the own-race bias (Walker & Hewstone, 2006), that (2) the own-race bias is weakened in individuals with expertise for other-race faces (Chiroro & Valentine, 1995) and that (3), an auto-associative network trained on a majority and a minority race of faces will exhibit face recognition performance that mim-

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ics the own-race bias in humans only when tuned to encoding individuating information between faces of the majority race of faces (Furl, Phillips, & O'Toole, 2002; O'Toole, Deffenbacher, Abdi, & Bartlett, 1991). These latter findings were interpreted by the authors as demonstrating perceptual tuning of the face recognition system to information that is useful for processing own-race faces and therefore limiting the quality of representations for other-race faces.

Additionally, different face processing stages may be modulated by face ethnicity to a variable extent. It is generally agreed that face recognition involves both featural and configural processing stages. Configural processing of faces can be further divided into three sub-phases (Maurer, Le Grand, & Mondloch, 2002)—first-order configural processing, i.e. the detection of basic features in a specific face-like spatial configuration, holistic processing, i.e. merging the different facial features into a gestalt, and second-order configural processing, i.e. perceiving the spatial distances between the different features. It has been shown that differential experience with own- and other-race faces affects perceptual face processing mechanisms in a qualitative way, so that own-race faces are processed more holistically than other-race faces (Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2004). Importantly, expertise seems to be associated with a greater use of configural information in faces (Rhodes, Brake, Taylor, & Tan, 1989). Thus, explanations of own-race bias effects in terms of enhanced configural processing can also be viewed as being expertise-based. In addition, these findings have been extended recently by demonstrating that not only configural, but also featural coding seem to be enhanced for own-race compared to other-race faces (Rhodes, Hayward, & Winkler, 2006). In sum, according to both of the discussed expertise-based models, the own-race bias should only decrease with higher long-term perceptual expertise with other-race faces.

In contrast to the above theories, others stress the role of situational context and of socio-cognitive processes. Accordingly, the own-race bias may be affected by a variety of factors, such as social categorization of a person as ingroup/outgroup member (Bernstein, Young, & Hugenberg, 2007; Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008), the homogeneity of facial appearance within ethnic groups (Chiroro, Tredoux, Radaelli, & Meissner, 2008), accessibility of encoding context memory (Horry & Wright, 2008) and emotional expression (Johnson & Fredrickson, 2005). Additionally, it has been suggested that the perception of a given face as an own- or other-race face (Michel, Corneille, & Rossion, 2007) may affect the own-race bias. However, this hypothesis was not supported in a very recent series of experiments, in which perceptual context was manipulated such that identical ambiguous-race morphed faces were perceived as either own- or other-race faces. No differences in discrimination and memory performance were observed for those faces, providing no support for a sociocognitive account of the own-race bias (Rhodes, Lie, Ewing, Evangelista, & Tanaka, 2010).

Most prominently, the race-feature hypothesis put forth by Levin (1996) assumes a mechanism in which the detection of an other-race-specifying feature in a given face leads to inferior processing, which is primarily driven by processing isolated category-defining visual features rather than by processing individual facial information (Levin, 2000). By contrast, own-race faces are suggested to be processed at an individual level, leading to relatively enhanced recognition memory. Crucially, it is proposed that participants do not fail to code individuating information because they *can't*, but because they simply *don't* (see Levin, 2000, p. 571). According to this hypothesis, one might expect the own-race bias to decrease, and recognition performance for other-race faces to increase, when prompting observers to process other-race faces at a deeper, more individual (or less categorical) level (cf. Sporer, 1991). This prediction is in strong contrast to the one derived from the expertise-based models described above.

The present study aimed at testing these models by investigating the effect of task demands during encoding on the resulting own-race bias. We compared two groups of participants who learned own- and other-race faces either at a task stressing discrimination of faces within both of these ethnic face groups (attractiveness rating) or between ethnic groups (ethnicity categorization). Given that this manipulation of directing participants' attention towards race-specifying features as opposed to other individual (and non-race-specifying) characteristics during learning was effective, situational theories would predict a decreased or even abolished own-race bias in participants in the attractiveness rating group. By contrast, if the own-race bias is only affected by long-term perceptual expertise, no task effects on the own-race bias should be apparent in participants who lack extensive experience with other-race faces.

1.2. Electrophysiological correlates

The own-race bias is a purely behavioural measure of own- and other-race face recognition accuracy and can therefore only measure the outcome of face processing mechanisms. By contrast, electrophysiological methods such as event-related potentials (ERP) allow for a more fine-grained chronometric assessment of the neural mechanisms mediating different processing stages in face perception (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Rugg & Coles, 1995), and may therefore help to reveal the underlying mechanisms.

In regard to the perception and memory of faces, several ERP components are of interest in this study. The earliest ERP component in this context is the P1, a positive deflection over occipital areas, peaking about 100 ms after onset of a visual stimulus. Since P1 is sensitive to basic stimulus properties such as contrast, luminance or spatial frequency (Schendan, Ganis, & Kutas, 1998) it has been assumed to reflect early visual processing (Luck, 2005) but is also modulated by spatial attention (Hillyard, Vogel, & Luck, 1998) and arousal (Vogel & Luck, 2000).

A prominent face-sensitive ERP component is the N170, a negative deflection maximal over right occipito-temporal sites (Bentin et al., 1996; but also see Rossion, Delvenne et al. (1999) and Bentin & Deouell, 2000), which has been interpreted to reflect structural encoding of faces (Eimer, 2000b). To account for the effect of generally greater N170 deflections to human faces compared to objects, two opposing theories have been put forward in regard to the underlying nature of the N170 component. While some argue for domain specificity of the N170 solely to human faces (e.g. Carmel & Bentin, 2002), others suggests the N170 to be a marker for expertise with a given stimulus class (Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002; Tanaka & Curran, 2001). In these studies, face-like N170 ERP responses were recorded in experts for non-face stimuli (Tanaka & Curran, 2001) and after extensive training with artificial stimuli (Rossion et al., 2002).

Apart from the stimulus domain and expertise with certain stimulus categories, N170 has also been shown to be influenced by inversion of faces, such that inverted faces resulted in a larger and delayed N170 (e.g. Eimer, 2000a; Itier & Taylor, 2002, 2004) compared to upright faces. Inversion is thought to disrupt configural and holistic processing (Maurer et al., 2002; for a review, see Rossion, 2008), which, as described above, has been shown to be larger to own-race as compared to other-race faces. However, evidence as to whether N170 is affected by face ethnicity is mixed, with some studies finding no ethnicity-dependent N170-modulations at all (Caldara, Rossion, Bovet, & Hauert, 2004; James, Johnstone, & Hayward, 2001), whereas other studies showed enhanced amplitudes in the N170 time range to own- compared to

other-race faces. The latter N170 amplitude effects did, however, appear at atypical N170 locations (Caldara et al., 2003) or with atypical reference settings (Ito & Urland, 2005). More recently, *decreased* N170 amplitudes to own-race faces as compared to other-race faces were reported (Herrmann et al., 2007; Walker, Silvert, Hewstone, & Nobre, 2008). A recent study (Stahl, Wiese, & Schweinberger, 2008) not only replicated these findings, but also showed that this N170 amplitude effect was accompanied by a latency effect, in which N170 peak latencies were delayed for Asian as compared to Caucasian faces. These effects were interpreted as reflecting earlier onset of configural processing of own-race faces. Although the reason for these discrepant findings remains unclear, it appears possible that some of the discrepancies are due to the experimental task used. Whereas most of the earlier studies mentioned above used categorization or passive viewing tasks, the latter three experiments adopted tasks which explicitly required participants to process faces for identity. Furthermore, a recent study on the effect of face inversion and ethnicity on ERP-correlates of face perception also demonstrated delayed N170 peaks to other-race faces, an effect which was independent of, and in addition to, the well-known N170 latency delay caused by inversion (Wiese, Stahl, & Schweinberger, 2009).

A second ERP component that has gained increasing attention over the last years is an occipito-temporal P2 component, which is characterized by a positive-going deflection over lateral occipito-temporal areas and a maximal peak between 200 and 250 ms. This P2 component has been found to be larger to photographic as compared to half-tone Mooney faces (Latinus & Taylor, 2006), to normal as compared to Thatcherized faces (Milivojevic, Clapp, Johnson, & Corballis, 2003) and to normal as compared to spatially distorted faces (Halit, de Haan, & Johnson, 2000). The P2 has been linked to the processing of spatial relations between facial features in individual faces (Latinus & Taylor, 2006) and the initiation of individual recognition mechanisms (Halit et al., 2000). Additionally and of particular interest to the present study, recent experiments showed larger P2 amplitudes to own- versus other-race faces (Stahl et al., 2008) as well as for young as compared to old faces (Wiese, Schweinberger, & Hansen, 2008). Taken together, the P2 component may be interpreted as being sensitive to the perceived typicality of face stimuli, and thus may be influenced by expertise. In line with this argumentation, the difference in the P2 for own- versus other-race faces was found to be largely reduced in a group of participants with long-term expertise for other-race faces (Stahl et al., 2008).

Finally, a late positive complex (LPC) characterized by a positive deflection at around 400 ms after stimulus onset has been shown to be larger for own-race than other-race faces when presented in an oddball-paradigm (Ito & Urland, 2003). Additionally, in recognition memory experiments learned ("old") stimuli elicited more positive amplitudes than new stimuli between approximately 400–700 ms after stimulus onset. This old/new effect has been shown to be maximal over left parietal electrodes to words (Rugg & Curran, 2007) and has been related to the conscious recollection of episodic memory and, more specifically, to the amount of recollected information (Vilberg, Moosavi, & Rugg, 2006). In addition to the literature on verbal memory, more positive amplitudes were also recorded for learned as compared to new faces (Paller et al., 2003; Paller, Gonsalves, Grabowecky, Bozic, & Yamada, 2000). In a very recent study, it has also been demonstrated that the scalp distribution of the old/new effect differs depending on the stimulus material (Yick & Wilding, 2008), with a more widely distributed old/new-effect for faces as compared to words.

1.3. The present study

In the present study, we aimed at investigating the influence of task demands during learning on both the behavioural own-race bias and electrophysiological correlates of memory for own-race (Caucasian) and other-race (Asian) faces in Caucasian participants. Following Levin's race-feature hypothesis (Levin, 2000), other-race faces are processed at a categorical level whereas own-race faces are processed individually, which is suggested as the basis for the own-race bias. Thus, directing participants' initial attention to non-race-specifying characteristics (as opposed to race-specifying features) for other-race faces should also increase recognition memory performance for these stimuli, and may in turn decrease the own-race bias. By contrast, expertise-based theories such as the MDFS model (Valentine & Endo, 1992) predict that a manipulation of ethnicity categorization versus attractiveness rating of other-race faces during learning does not affect the own-race bias. In addition to that, previous studies in our lab always adhered to a common experimental design in which participants had to categorize faces according to ethnicity during learning—a task that according to Levin (2000) might have affected the behavioural outcome of our studies. To test between the above named competing theoretical explanations and to assess possible design effects on the own-race bias, participants in the present study were instructed to either rate the attractiveness of faces on a 6-point scale (attractiveness rating task) or to categorize faces according to their ethnicity (categorization task) in the learning phases of a recognition memory experiment. In subsequent test phases, participants were required to differentiate learned ("old") from unfamiliar ("new") faces.

With regard to ERP-correlates of own- and other-race face processing, we first expected to replicate previous results showing N170-modulations by face ethnicity, with enhanced N170-amplitudes and delayed N170-peaks to other-race faces as compared to own-race faces (Stahl et al., 2008). Second, an occipito-temporal P2 component has been shown to be more pronounced to own-race compared with other-race faces in a group of non-experts, whereas a group of experts did not exhibit P2 amplitude differences to own- and other-race faces (Stahl et al., 2008). We hypothesized that experts recruit individual recognition mechanisms to a greater extent than non-experts for own- as well as other-race faces. If task demands indeed had an effect on encoding mechanisms for other-race faces, we would expect P2 effects in the attractiveness rating group to be similar to the P2 effects observed in experts by Stahl et al. (2008), whereas P2 effects in the categorization group should be similar to the P2 effects observed in novices. Accordingly, similar P2 amplitudes for own- and other-race faces should be seen in the attractiveness rating group, whereas more positive P2 amplitudes to own-race faces should be seen in the categorization group. Finally, we wanted to test for ethnicity-dependent modulations of the LPC and ERP old/new effects. If the attractiveness rating task triggered more fine-grained processing of own- and other-race faces, we would expect retrieval of more detailed information about individual faces at test, and thus increased old/new effects for participants in the attractiveness rating group as compared to the categorization group.

2. Methods

2.1. Participants

Forty-four Caucasian undergraduate students from the University of Jena participated in the study, and were compensated with course credit or with a payment of € 5/h. All participants were right-handed, according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971), and reported normal or corrected-to-normal vision. Four participants were excluded from statistical analyses due to poor quality of the EEG-recordings. The remaining participants were evenly distributed over both experimental conditions, and the resulting experimental groups of 20 participants each did not differ regarding gender distribution (75% female each). Analysis of participant age did not reveal differences between attractiveness rating group ($M = 24.35$ years ± 5.48 SD) and categorization group

($M = 22.35$ years $\pm$ 2.91 SD; $t[38] = 1.44$, $p > .05$). All participants gave informed written consent, and the study was conducted in accordance with the Declaration of Helsinki.

2.2. Stimuli

Stimuli consisted of 120 unfamiliar Caucasian (own-race) and 120 unfamiliar Asian (other-race) faces (50% female, respectively). All stimuli showed front-view faces with neutral expression, the majority of which were taken from the CAL/PAL Database (Minear & Park, 2004). Using Adobe Photoshop™, all stimuli were edited in order to substitute the existing background with a uniform black background. Subsequently, stimuli were converted to gray-scale and cropped to a size of 170 × 216 pixels (6.0 × 7.6 cm), resulting in a visual angle of 3.8° × 4.8° at a viewing distance of 90 cm.

2.3. Procedure

Participants were seated in front of a computer screen in a dimly lit, electrically shielded and noise-attenuated chamber (400-A-CT-Special, Industrial Acoustics, Niederkrüchten, Germany) with their heads in a chin rest so as to provide for a constant viewing distance of 90 cm. All participants were assigned to one of two experimental groups with the only difference between those groups being the learning task in the recognition memory experiment.

For both groups of participants, the experiment consisted of a practice block (24 trials) and 6 experimental blocks. Each block was divided into a learning and a test phase. Individual trials always adhered to the same pattern: first, a fixation cross was displayed for a duration of 500 ms, followed by stimulus presentation for either 5000 ms (learning phase) or 2000 ms (test phase). Each trial ended with a blank screen, which was presented for 500 ms. Participants had to respond via button presses within 5000 ms (learning phase) or 2000 ms (test phase) after stimulus onset, respectively. During each learning phase 10 Asian and 10 Caucasian faces (50% female, respectively) were presented to the participants, who were instructed to decide as fast and accurately as possible how attractive a given face was to them (attractiveness rating group, attractiveness rating on a 6-point scale from "1" = very attractive to "6" = very unattractive) or whether a given face was Asian or Caucasian (categorization group, ethnicity categorization). In addition, participants were instructed to memorize each individual face. Learning and test phases were separated by a 30 s break. During the ensuing test phase, all 20 faces from the directly preceding learning phase as well as 20 new faces were presented intermixed in a pseudo-randomized order, ensuring that at least five other faces were displayed between the presentation of an identical face in the learning and the subsequent test phase. Participants had to decide as fast and accurately as possible whether a given face had been presented in the directly preceding learning phase ("learned") or not ("new"). Between experimental blocks, participants were allowed a self-timed period of rest. Key assignment and allocation of stimuli to learned and non-learned conditions was counterbalanced across participants.

2.4. Behavioural data

Reaction times (RT) and responses were recorded and analyzed during learning and test phases. For learning phases, responses and mean RTs were analyzed for Asian and Caucasian faces separately for each group, since learning tasks differed greatly in regard to complexity and responses. For the test phases, responses were sorted into four different categories for both Asian and Caucasian faces: hits (correctly identified learned faces), misses (learned faces incorrectly classified as new), false alarms (FA, new faces incorrectly classified as learned) and correct rejections (CR, correctly classified new faces). Measures of sensitivity (d') and response criterion (C) were calculated for both Asian and Caucasian faces in each group of participants according to signal-detection theory (cf. Green & Swets, 1966):

$$d' = z(\text{hits}) - z(\text{FA}) \quad \text{and} \quad C = -\frac{1}{2}[z(\text{hits}) + z(\text{FA})].$$

Furthermore, measures for the Own-Race Bias (ORB) were calculated according to Macmillan and Creelman (1991) using the following formula:

$$\text{ORB} = \frac{d'_{\text{OR}} - d'_{\text{SR}}}{d'_{\text{OR}} + d'_{\text{SR}}},$$

with d'_{OR} indicating sensitivity measures for other-race faces and d'_{SR} indicating sensitivity values for same-race faces (own-race faces).

Behavioural data from the learning phases (reaction times, responses) were analyzed separately for each experimental group. Analysis of attractiveness ratings was achieved by employing a Wilcoxon test. Analysis of accuracy data from the learning phase in the categorization task condition was omitted due to ceiling effects. Whereas reaction times from the learning phases were analyzed individually for each group by using t-tests, reaction times from test phases were analyzed with a mixed-model ANOVA with the within-subject factors "face ethnicity" (Asian, Caucasian) and "response" (hits, CR) as well as the between-subject factor "group". Additionally, z-transformed measures such as d' and response bias (C) were evaluated using non-parametric tests (U-Test, Wilcoxon-Test) for comparison of differences in regard to participant group and face ethnicity.

2.5. Electrophysiological recording and analysis

EEG was recorded using a 32-channel BioSemi Active II system (BioSemi, Amsterdam, Netherlands). Active sintered Ag/AgCl-electrodes were mounted in an elastic cap with recording sites at Fz, Cz, Pz, Iz, FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, F9, F10, FT9, FT10, TP9, TP10, P9, P10, PO9, PO10, I1 and I2. EEG was recorded continuously with a 256-Hz sampling rate from DC to 75 Hz. Please note that BioSemi systems work with a "zero-Ref" setup with ground and reference electrodes replaced by a so-called CMS/DRL circuit (cf. to http://www.biosemi.com/faq/cms&drl.htm for further information).

Contributions of blink artefacts were corrected using the algorithm implemented in BESA 5.1 (Berg & Scherg, 1994). Subsequently, EEG was segmented from −200 until 1200 ms relative to stimulus onset, with the first 200 ms as baseline. Only trials with correct responses in the learning and test phase (hit, CR) entered the analysis. Trials contaminated by non-ocular artefacts and saccades were rejected from further analysis. Artefact rejection was carried out using the BESA 5.1 tool, with an amplitude threshold of 100 μV, as well as a gradient criterion rejecting all trials differing by more than 75 μV between two consecutive data points. The remaining trials were recalculated to average reference, averaged according to experimental condition and digitally low-pass filtered at 20 Hz (12 db/oct, zero phase shift). Therefore, three different waveforms (learning phase, hits, CR) were calculated for each ethnicity and participant group, namely Caucasian faces (learning phases), Asian faces (learning phases), Caucasian faces (hits), Caucasian faces (CR), Asian faces (hits) and Asian faces (CR).

For statistical analyses, ERP components were analyzed at the electrodes of their respective maximal amplitudes. Therefore, P1 latency was analyzed at I1 and I2 between 80 and 140 ms, whereas N170 latency was determined at P9 and P10 between 120 and 180 ms after stimulus onset with the exemption of one participant, who showed a clear N170 only at electrodes PO9 and PO10. In this case N170 latency and peak amplitude measures were calculated for PO9 and PO10. Individual peak amplitudes relative to a 200 ms baseline were determined at I1 and I2 for the P1 component and at P9 and P10 for the N170 component (with the exemption mentioned above). For later time segments, mean amplitudes relative to a 200 ms baseline were computed for the P2 component between 190 and 220 ms at P9 and P10, whereas mean amplitudes for the late positive component and the Old/New-Effect were calculated between 400 and 600 ms at frontal, central and parietal electrodes (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4). Statistical analysis of ERPs for P1, N170 and P2 from the learning phases was performed by using mixed model ANOVAs with the within-subject factors "hemisphere" and "face ethnicity" as well as the between-subject factor "group". Analyses of ERPs for the test phases included an additional within-subject factor "response" (hits vs. CR). Finally, analyses for the LPC and Old/New-Effect required two additional within-subject factors "anterior/posterior position" (frontal, central and posterior) and "laterality" (left, midline and right; replacing the factor "hemisphere") to account for the various electrode positions that were entered into the analyses. For all analyses, degrees of freedom were corrected according to Huynh-Feldt where appropriate and significant interactions were followed up by pairwise comparisons.

3. Results

3.1. Behavioural results

3.1.1. Learning phases

In the attractiveness rating group, attractiveness ratings (from 1 = "very attractive" to 6 = "very unattractive") for Asian ($M = 3.83$, $SD = 0.61$) and Caucasian faces ($M = 3.79$, $SD = 0.51$) were statistically analysed by using a Wilcoxon-Test, which yielded no significant differences ($z = -0.019$, $p > .05$) between Asian and Caucasian faces.

Mean reaction times (cf. Table 1) from the learning phases were analysed separately for each participant group by using t-Tests. Whereas comparison of reaction times in the attractiveness rating group did not reveal any significant differences between responses to Asian and Caucasian faces ($t[19] = -0.49$, $p > .05$), participants in the categorization group responded significantly faster to Asian than Caucasian faces ($t[19] = -2.42$, $p < .05$).

3.1.2. Test phases

Reaction times (cf. Table 1) were analysed by using a mixed-model ANOVA with the between-subject factor "group" and the within-subject factors "face ethnicity" and "response" (hits, CR), which resulted in significant main effects for "face ethnicity"

Table 1
Mean values and standard errors for response criterion (*C*), accuracies (*d′*), own-race bias and reaction times for learning and test phases in attractiveness rating and categorization groups.

		Attractiveness rating		Categorization	
		M	SE_M	*M*	SE_M
Learning phases					
RTs (ms)	Caucasian	1666.48	101.17	886.61	52.18
	Asian	1679.20	94.95	855.93	53.39
Test phases					
RTs (ms)	Caucasian (hits)	925.22	25.14	931.90	34.29
	Caucasian (CR)	986.38	26.58	995.08	37.57
	Asian (hits)	977.79	36.20	994.47	37.36
	Asian (CR)	1044.26	37.57	1041.73	36.48
C	Caucasian	0.18	0.07	0.12	0.06
	Asian	0.05	0.08	0.07	0.06
d′					
	Caucasian	2.20	0.11	2.06	0.12
	Asian	1.44	0.13	1.47	0.12
Own-Race Bias					
		−0.22	0.03	−0.19	0.03

($F[1,38] = 47.77$, $p < .001$) and "response" ($F[1,38] = 37.89$, $p < .001$). Subsequent post hoc *t*-Tests showed that RTs were significantly faster to Caucasian faces compared with Asian faces ($t[39] = 7.00$, $p < .001$) and to learned faces (hits) compared with new faces (Correct Rejections; $t[39] = -6.22$, $p < .001$). Analysis of *d′* and response criterion (*C*; for an overview, cf. Table 1) was performed by using nonparametric tests for comparisons of between- and within-group effects. Comparison of *d′* between groups was achieved by computing a Mann-Whitney *U*-Test, which yielded no significant group differences both in *d′* to Caucasian ($z = -0.514$, $p > .05$) and Asian faces ($z = -0.081$, $p > .05$). Further analysis of *d′* by means of Wilcoxon-Tests for each group yielded significantly higher *d′* to Caucasian as compared to Asian faces in both attractiveness rating ($z = -3.920$, $p < .001$) and categorization group ($z = -3.659$, $p < .001$). Finally, comparison of the measures for the own-race bias did not reveal any significant differences between experimental groups ($z = -0.718$, $p > .05$). A Mann-Whitney *U*-Test of response criterion (*C*) yielded no significant differences between groups in responses to both Asian ($z = -0.081$, $p > .05$) and Caucasian faces ($z = -0.541$, $p > .05$). This finding was reflected in subsequent group-wise Wilcoxon-Tests where no significant differences in response bias to Caucasian and Asian faces were found in both attractiveness rating ($z = -1.755$, $p > .05$) and categorization group ($z = -1.139$, $p > .05$).

3.2. Electrophysiological results

3.2.1. Learning phases

P1: ANOVA of P1 latency (cf. Table 2) at I1 and I2 with the within-subject factors "hemisphere" and "face ethnicity" and the between-subject factor "group" revealed no significant main effects or interactions (all $p > .05$). An ANOVA of P1 amplitude at electrodes I1 and I2 (cf. Table 2) with the same factors revealed significant main effects for "hemisphere" ($F[1,38] = 7.89$, $p < .05$), reflecting enhanced amplitudes over the right hemisphere, and "group" ($F[1,38] = 4.58$, $p < .05$), with generally higher amplitudes in the categorization group. In addition, a significant interaction of "hemisphere x face ethnicity" ($F[1,38] = 5.86$, $p < .05$) was found, which indicated enhanced amplitudes to Asian faces over the right hemisphere only ($t[39] = -2.28$, $p < .05$).

N170: A corresponding ANOVA for N170 latency at P9 and P10 (cf. Table 2) yielded a significant main effect for "face ethnicity" ($F[1,38] = 45.8$, $p < .001$), indicating later peaks for Asian faces in both groups, and a significant interaction of "hemisphere × face ethnicity" ($F[1,38] = 4.5$, $p < .05$), with increased differences for own- vs. other-race faces over the right hemisphere. An analysis of N170 peak amplitude at P9 and P10 revealed a main effect of "hemisphere" ($F[1,38] = 8.32$, $p < .05$) only, with more negative amplitudes over the right hemisphere (Figs. 1 and 2).

P2: An ANOVA for the P2 at P9 and P10 (cf. Table 2) revealed a significant main effect of "face ethnicity" ($F[1,37] = 12.91$, $p < .001$) which was qualified by a significant interaction "face ethnicity × group" ($F[1,37] = 4.94$, $p < .05$). Further group-wise analyses of P2 mean amplitudes showed a significant main effect of "face ethnicity" in the categorization group only ($F[1,19] = 30.06$, $p < .001$), with higher amplitudes for Caucasian compared to Asian faces, whereas no such differences were found in the attractiveness rating group ($F[1,19] = 0.09$, $p > .05$) (Figs. 1 and 2).

3.2.2. Late positive complex

LPC amplitudes (cf. Table 3) were analyzed at F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 with the between-subject factor "group" and the within-subject factors "face ethnicity", and additional topographical factors for "anterior/posterior position" and "laterality". There were significant main effects for "anterior/posterior position" ($F[2,76] = 137.90$, $p < .001$), "laterality" ($F[1.8,70.5] = 3.81$,

Table 2
ERP measures for P1, N170 and P2 during the learning phases.

		Attractiveness rating				Categorization			
		M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M
P1 latency (ms)		I1		I2		I1		I2	
	Caucasian	107.95	2.82	109.30	2.39	110.20	2.82	110.40	2.39
	Asian	108.25	2.99	109.85	2.71	109.15	2.99	111.15	2.71
P1 amplitude (μV)		I1		I2		I1		I2	
	Caucasian	5.468	0.54	6.465	0.74	7.684	0.54	8.499	0.74
	Asian	5.447	0.49	6.711	0.67	7.371	0.49	8.860	0.67
N170 latency (ms)		P9		P10		P9		P10	
	Caucasian	157.95	2.86	153.60	3.29	159.75	3.78	155.55	2.78
	Asian	159.95	3.05	157.65	3.19	160.75	3.65	159.45	3.02
N170 amplitude (μV)		P9		P10		P9		P10	
	Caucasian	−5.546	0.74	−7.251	1.14	−4.805	0.86	−6.228	0.76
	Asian	−5.365	0.75	−7.488	1.15	−4.931	0.92	−6.633	0.75
P2 mean amplitudes (μV, 190–220 ms)		P9		P10		P9		P10	
	Caucasian	−2.716	0.74	−2.741	1.11	−2.111	0.82	−2.726	0.92
	Asian	−2.757	0.68	−3.229	1.00	−3.139	0.89	−3.738	0.96

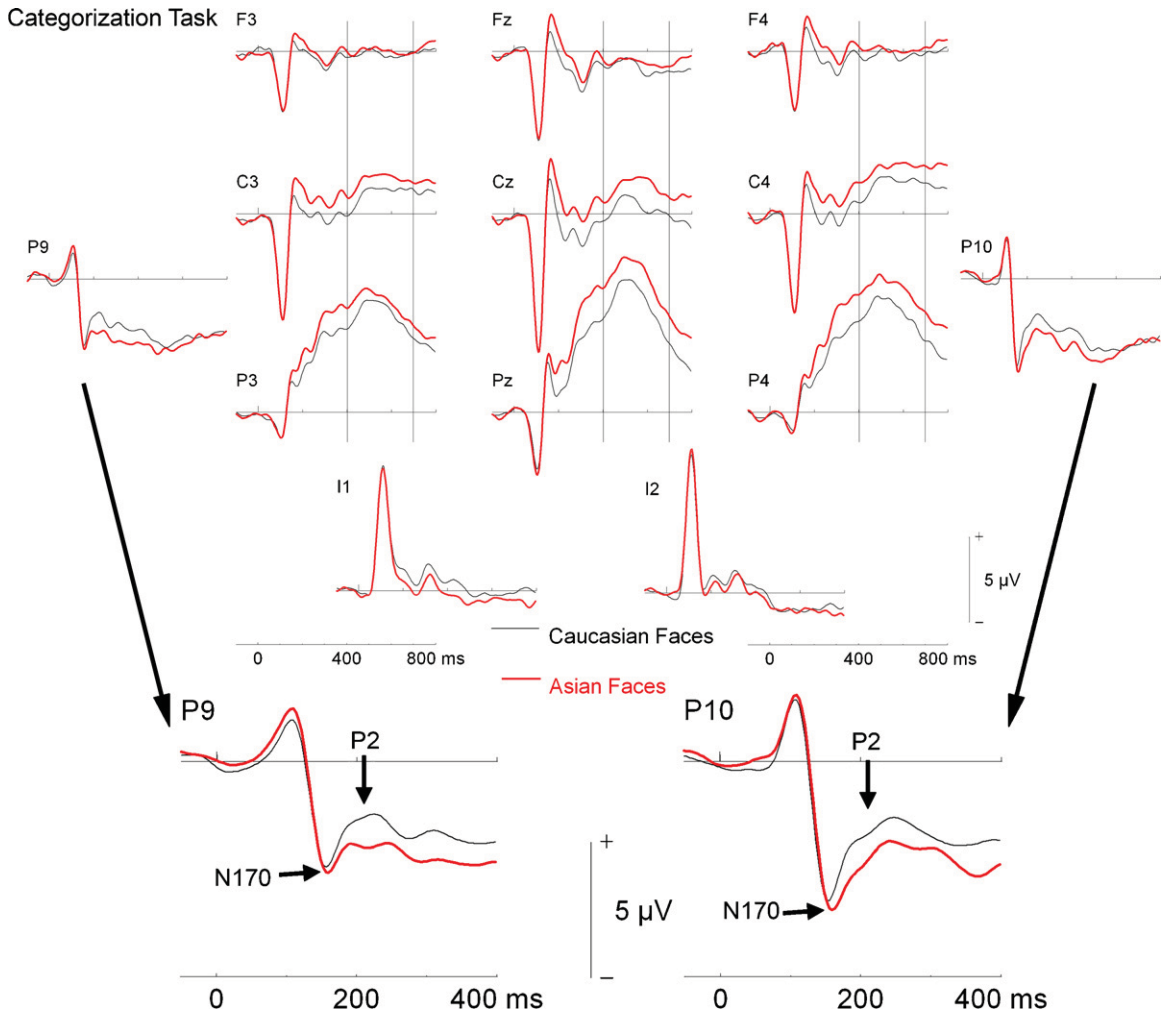

Fig. 1. Grand Mean waveforms for Asian and Caucasian faces during learning phases in the categorization group. ERPs are plotted from −100 to 800 ms for all electrodes and from −50 to 400 ms for P9 and P10. Note the P2 effects of face ethnicity and learning task (as indicated by arrows).

$p < .05$) and "face ethnicity" ($F[1,38] = 5.27$, $p < .05$). These main effects were further qualified by significant interactions of "face ethnicity x group" ($F[1,38] = 9.62$, $p < .05$), "anterior/posterior position × laterality" ($F[4,152] = 6.11$, $p < .001$) and "anterior/posterior position × face ethnicity × group" ($F[1.8,69.5] = 3.22$, $p < .05$). Subsequent group-wise analyses revealed significant main effects of "anterior/posterior position" ($F[2,38] = 44.53$, $p < .001$) and "laterality" ($F[2,38] = 5.23$, $p < .05$) as well as a significant interaction of "anterior/posterior position × laterality" ($F[4,76] = 3.07$, $p < .05$) in the attractiveness rating group, whereas no main effect or interaction involving the "face ethnicity" factor was to be found (all $p > .05$). In the categorization group, however, significant main effects of "face ethnicity" ($F[1,19] = 10.27$, $p < .05$), with higher amplitudes to Asian compared with Caucasian faces, and "anterior/posterior" ($F[2,38] = 105.92$, $p < .001$) as well as significant interactions of "anterior/posterior position × laterality" ($F[4,76] = 3.87$, $p < .05$) and "anterior/posterior position × face ethnicity" ($F[1.5,30.0] = 3.75$, $p < .05$) were found, with larger amplitude differences between own- and other-race faces at posterior electrode positions (Figs. 1 and 2).

3.3. Test phases

P1: An ANOVA of P1 latency at I1 and I2 (cf. Table 4) yielded a significant interaction of "hemisphere × face ethnicity" ($F[1,38] = 6.93$, $p < .05$). Subsequent comparisons for each hemisphere indicated a trend for delayed P1 peaks to Caucasian faces over the left hemisphere ($t[39] = 1.90$, $p = .064$), but not over the right hemisphere ($t[39] = -1.59$, $p > .05$). ANOVA of P1 amplitude at I1 and I2 revealed only a significant main effect of "hemisphere" ($F[1,38] = 7.53$, $p < .05$), indicating generally larger P1 peaks over the right hemisphere.

N170: Analysis for N170 latency at P9 and P10 (cf. Table 4) revealed a main effect of "face ethnicity" ($F[1,38] = 61.36$, $p < .001$), reflecting later peaks for Asian faces compared with Caucasian faces in both groups, and a trend for an interaction of "face ethnicity × group" ($F[1,38] = 4.07$, $p = .051$), pointing towards numerically greater latency differences in the categorization group as compared to the attractiveness rating group (cf. Table 4). A subsequent analysis of N170 amplitude at P9 and P10 yielded significant main effects of "hemisphere" ($F[1,38] = 6.69$, $p < .05$), with larger amplitudes over the right hemisphere, and "face ethnicity" ($F[1,38] = 4.89$, $p < .05$), indicating larger amplitudes to Asian compared with Caucasian faces (Figs. 3 and 4).

P2: Analysis of P2 mean amplitudes (cf. Table 2) yielded a significant main effect of "face ethnicity" ($F[1,38] = 28.02$, $p < .001$) as well as a significant interaction of "hemisphere × face ethnicity × group" ($F[1,38] = 6.34$, $p < .05$). Post hoc *t*-Tests of mean amplitudes showed significantly higher amplitudes to Caucasian faces over both left ($t[19] = 5.05$, $p < .001$) and right hemisphere ($t[19] = 2.21$, $p < .05$) in the categorization group, whereas in the attractiveness rating group larger P2 mean amplitudes to Caucasian faces were

Table 3
mean amplitudes (400–600 ms) for LPC and old/new-effect in learning and test phases, respectively.

		Attractiveness rating				Categorization				
		M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M	
LPC (μV, 400–600 ms)		Caucasian		Asian		Caucasian		Asian		
F3		0.059	0.66	0.223	0.71	−0.188	0.55	−0.011	0.49	
Fz		0.645	0.73	0.374	0.66	−0.940	0.46	−0.674	0.56	
F4		1.088	0.71	1.170	0.78	−0.229	0.32	0.071	0.40	
C3		1.386	0.84	1.141	0.77	1.220	0.54	1.981	0.68	
Cz		2.168	0.99	2.201	0.88	0.379	0.59	1.613	0.61	
C4		3.399	0.74	3.289	0.74	1.790	0.45	2.667	0.61	
P3		5.651	0.62	5.043	0.63	5.774	0.54	6.450	0.49	
Pz		6.642	0.83	6.334	0.71	6.433	0.75	7.896	0.83	
P4		5.963	0.67	5.883	0.63	5.880	0.67	7.240	0.64	
Old/new-effect (μV, 400–600 ms)			Caucasian		Asian		Caucasian		Asian	
F3	Old	0.017	0.75	−0.597	0.58	0.408	0.36	0.114	0.34	
	New	0.242	0.49	0.202	0.62	−0.062	0.29	−0.095	0.34	
Fz	Old	0.087	0.72	−0.25	0.69	0.192	0.56	−0.582	0.60	
	New	−1.042	0.63	−1.14	0.68	−0.468	0.51	−0.642	0.57	
F4	Old	0.663	0.72	0.074	0.74	0.489	0.55	0.381	0.53	
	New	−0.547	0.56	−0.642	0.72	−0.106	0.42	−0.290	0.45	
C3	Old	0.981	0.74	0.755	0.71	2.181	0.55	2.485	0.55	
	New	0.812	0.69	0.742	0.82	1.442	0.57	2.149	0.56	
Cz	Old	1.394	1.02	1.281	0.94	2.169	2.49	2.157	2.17	
	New	1.186	1.04	0.873	0.99	1.346	2.15	1.834	0.82	
C4	Old	3.067	0.73	2.431	0.81	2.867	0.69	3.534	0.71	
	New	1.513	0.72	1.547	0.75	2.509	0.65	2.682	0.65	
P3	Old	4.606	0.65	4.832	0.62	6.022	0.62	6.199	0.54	
	New	3.870	0.44	4.295	0.54	5.376	0.56	6.069	0.58	
Pz	Old	5.564	0.73	6.189	0.65	7.192	0.85	8.151	1.08	
	New	5.631	0.68	6.008	0.71	6.500	0.96	7.665	1.10	
P4	Old	4.909	0.59	4.876	0.55	5.950	0.75	7.259	0.64	
	New	4.422	0.58	5.015	0.54	5.665	0.68	6.725	0.65	

Table 4
ERP measures for P1, N170 and P2 during the test phases.

		Attractiveness rating				Categorization			
		M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M
P1 latency (ms)		I1		I2		I1		I2	
	Caucasian (hits)	106.60	2.51	107.10	2.32	108.60	2.97	108.50	1.89
	Caucasian (CR)	107.20	2.63	106.65	2.29	110.15	2.69	108.65	1.99
	Asian (hits)	104.90	2.86	106.30	2.28	108.75	2.82	110.20	2.11
	Asian (CR)	104.95	2.93	107.85	2.42	108.30	2.89	109.75	1.75
P1 amplitude (μV)		I1		I2		I1		I2	
	Caucasian (hits)	5.633	0.53	6.785	0.81	7.523	0.94	8.670	0.89
	Caucasian (CR)	5.519	0.55	6.476	0.69	7.400	0.89	8.185	0.82
	Asian (hits)	5.795	0.49	6.745	0.64	7.619	0.88	8.925	0.90
	Asian (CR)	5.475	0.54	6.746	0.70	7.302	0.77	8.799	0.88
N170 latency (ms)		P9		P10		P9		P10	
	Caucasian (hits)	154.05	3.06	151.00	2.67	155.10	3.55	153.05	2.89
	Caucasian (CR)	153.55	2.73	150.40	2.97	156.30	3.43	152.25	2.75
	Asian (hits)	157.00	3.29	153.20	2.94	159.35	3.17	155.75	2.91
	Asian (CR)	155.10	3.14	153.00	2.77	159.60	3.68	157.75	2.92
N170 amplitude (μV)		P9		P10		P9		P10	
	Caucasian (hits)	−5.057	0.73	−7.453	1.18	−4.883	0.93	−6.047	0.57
	Caucasian (CR)	−5.157	0.75	−6.994	1.17	−4.973	0.91	−5.771	0.48
	Asian (hits)	−5.392	0.81	−7.489	1.19	−5.394	0.79	−6.144	0.78
	Asian (CR)	−5.079	0.84	−7.566	1.14	−5.135	0.87	−6.521	0.64
P2 mean amplitudes (μV, 190–220 ms)		P9		P10		P9		P10	
	Caucasian (hits)	−1.302	0.62	−1.645	1.19	−1.541	0.86	−1.808	0.89
	Caucasian (CR)	−1.562	0.70	−1.239	1.14	−1.468	0.92	−1.624	0.82
	Asian (hits)	−1.875	0.60	−2.661	1.09	−2.954	0.84	−2.417	0.99
	Asian (CR)	−1.646	0.69	−2.321	1.02	−2.762	0.91	−2.524	0.98

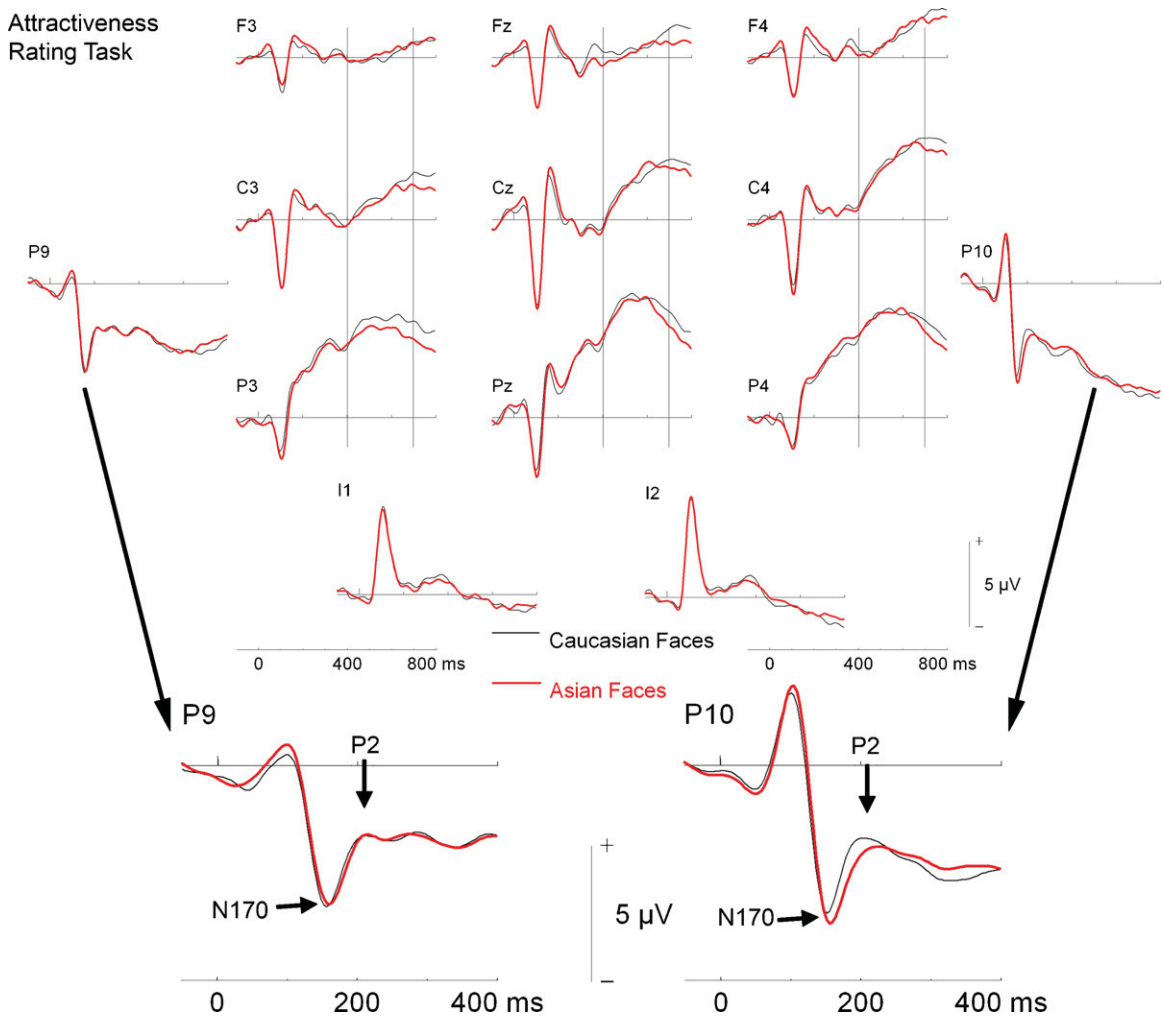

Fig. 2. Grand Mean waveforms for Asian and Caucasian faces during learning phases in the attractiveness rating group. ERPs are plotted from −100 to 800 ms for all electrodes and from −50 to 400 ms for P9 and P10. Note the P2 effects of face ethnicity and learning task (as indicated by arrows).

evident only over the right hemisphere ($t[19] = 3.36$, $p < .05$), but not over the left hemisphere ($t[19] = 1.25$, $p > .05$) (Figs. 3 and 4).

3.4. Old/new-effect

For the test phases, mean amplitudes in the time window of the Old/New-effect (cf. Table 3) were analyzed over F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 with the between-subject factor "group" and the within-subject factors "face ethnicity", "response", "anterior/posterior position" and "laterality". An ANOVA of the Old/New-Effect yielded significant main effects for "anterior/posterior position" ($F(2,76] = 130.74$, $p < .001$), "response" ($F[1,38] = 25.56$, $p < .001$) and significant interactions of "anterior/posterior position × laterality" ($F[4,152] = 10.03$, $p < .001$), "anterior/posterior position × face ethnicity" ($F[2,76] = 19,34$, $p < .001$), "anterior/posterior position × laterality × response × group" ($F[4,152] = 3.02$, $p < .05$) and "laterality × face ethnicity × response × group" ($F[1.8,69.5] = 3.25$, $p < .05$). Since we were mainly interested in the interaction of face ethnicity and learning task, we focused on analyzing the four-way interaction of "laterality × face ethnicity × response × group" and calculated separate ANOVAs for each lateral position (left, midline and right) with amplitudes averaged across "anterior/posterior position" individually for each group with the factors "face ethnicity" and "response". For the attractiveness rating group, significant main effects of "response" were found at midline ($F[1,19] = 4.98$, $p < .05$) and right-hemispheric electrode positions ($F[1,19] = 22.02$, $p < .001$). Furthermore, a significant interaction of "face ethnicity × response" ($F[1,19] = 5.93$, $p < .05$) was evident over the right hemisphere, indicating a larger Old/New-Effect for Caucasian compared to Asian faces. In contrast, further analyses of the Old/New-Effect in the categorization group revealed significant main effects of "response" over left-hemispheric ($F[1,19] = 6.72$, $p < .05$), midline ($F[1,19] = 11.0$, $p < .05$) and right-hemispheric electrodes ($F[1,19] = 12.83$, $p < .05$), but no significant interactions of "face ethnicity × response" (all $p > .05$) (Figs. 3 and 4).

4. Discussion

By manipulating the learning task in a recognition memory experiment in two groups of participants, the present study aimed at testing two theoretical accounts of the own-race bias. In addition to the comparison of the behavioural own-race bias in both groups, ERPs were recorded and analyzed regarding ethnicity- and task-dependent modulations.

4.1. Behavioural results

At the behavioural level, both groups – regardless of the experimental condition – exhibited a clear own-race bias. Importantly, while participants from the attractiveness rating group did exhibit comparable processing for own- and other-race faces with respect

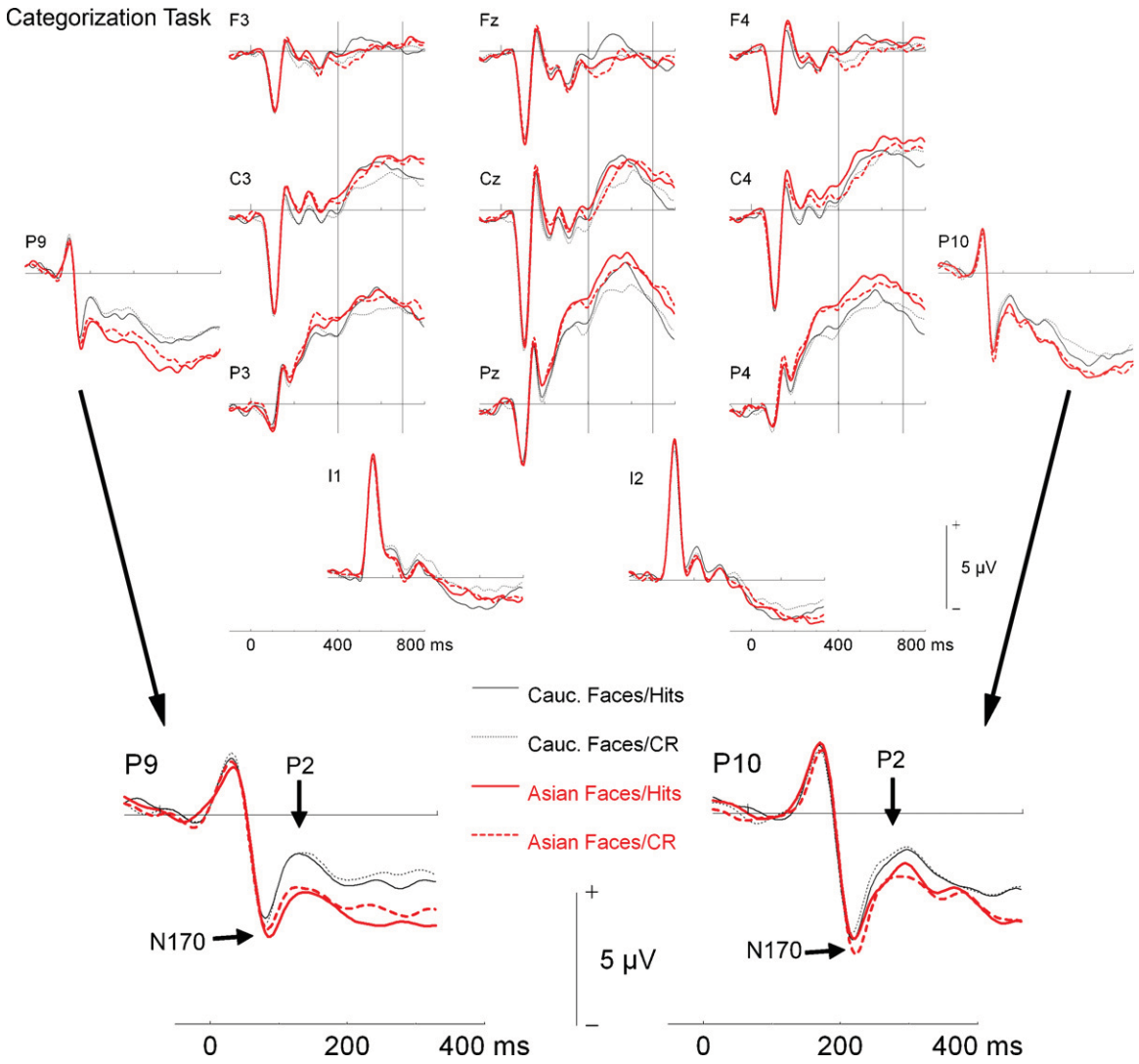

Fig. 3. Grand Mean waveforms for Asian and Caucasian faces during test phases in the categorization group. ERPs are plotted from −100 to 800 ms for all electrodes and from −50 to 400 ms for P9 and P10. Note the P2 effects of face ethnicity and learning task (as indicated by arrows).

to RTs and mean attractiveness rating, they did not show a significantly lower own-race bias, as might have been expected on the basis of Levin's race-feature hypothesis (Levin, 2000). According to this theory, the other-race effect occurs because people code race-specifying features at the cost of individuating information, that is, same-race faces are processed with an "exemplar" strategy, whereas other-race (or more generally "out-group") faces are processed with a "prototype" strategy. Because recognition memory depends on individuating information, performance at test is better for same- compared to other-race faces. Crucially, participants do not fail to code individuating information because they *can't*, but because they simply *don't* (see Levin, 2000, p. 571). Thus, the theory would predict that, although participants have sufficient time and knowledge about the recognition memory test, they simply do not process individuating information for other-race faces to the same degree as they do for own-race faces. If, however, the task during learning encourages participants to direct their attention to non-race-specifying characteristics in both same- and other-race faces, this may alleviate the own-race bias. The attractiveness rating task in the present study fulfilled this requirement of directing the processing of faces of both ethnicities towards dimensions other than ethnic category for the following reason: For both Asian and Caucasian faces, both highly attractive and less attractive faces were presented during the experiment. Accordingly, participants could not process Asian faces at a group or category level, but needed to differentiate between both Asian and Caucasian faces in terms of attractiveness (measured in 6 stages). In other words, participants had to differentiate between individual faces *within* each of the ethnic categories, while the categorization task required to differentiate *between* ethnic categories.

It has to be noted though, that the learning conditions examined in the present study did not directly operationalize the concepts of 'categorization' versus 'individuation' as described by Levin (1996, 2000). More specifically, the attractiveness-rating task did not necessarily induce 'individuation' in the strict sense, since neither was an individual label nor a unique rating requested for each individual face. In addition, it could be argued that the instruction *per se* to memorize the faces, which was given in both learning conditions, might constitute an individuation task. These constraints clearly limit the theoretical implications of the present results with respect to the race-feature theory.

However, with regard to the notion that the attractiveness rating task did not necessarily induce individuation, it needs to be noted that both behavioural and ERP measures (see below) indicated highly similar processing of same- and other-race faces during attractiveness ratings. Critically, there is thus no evidence that

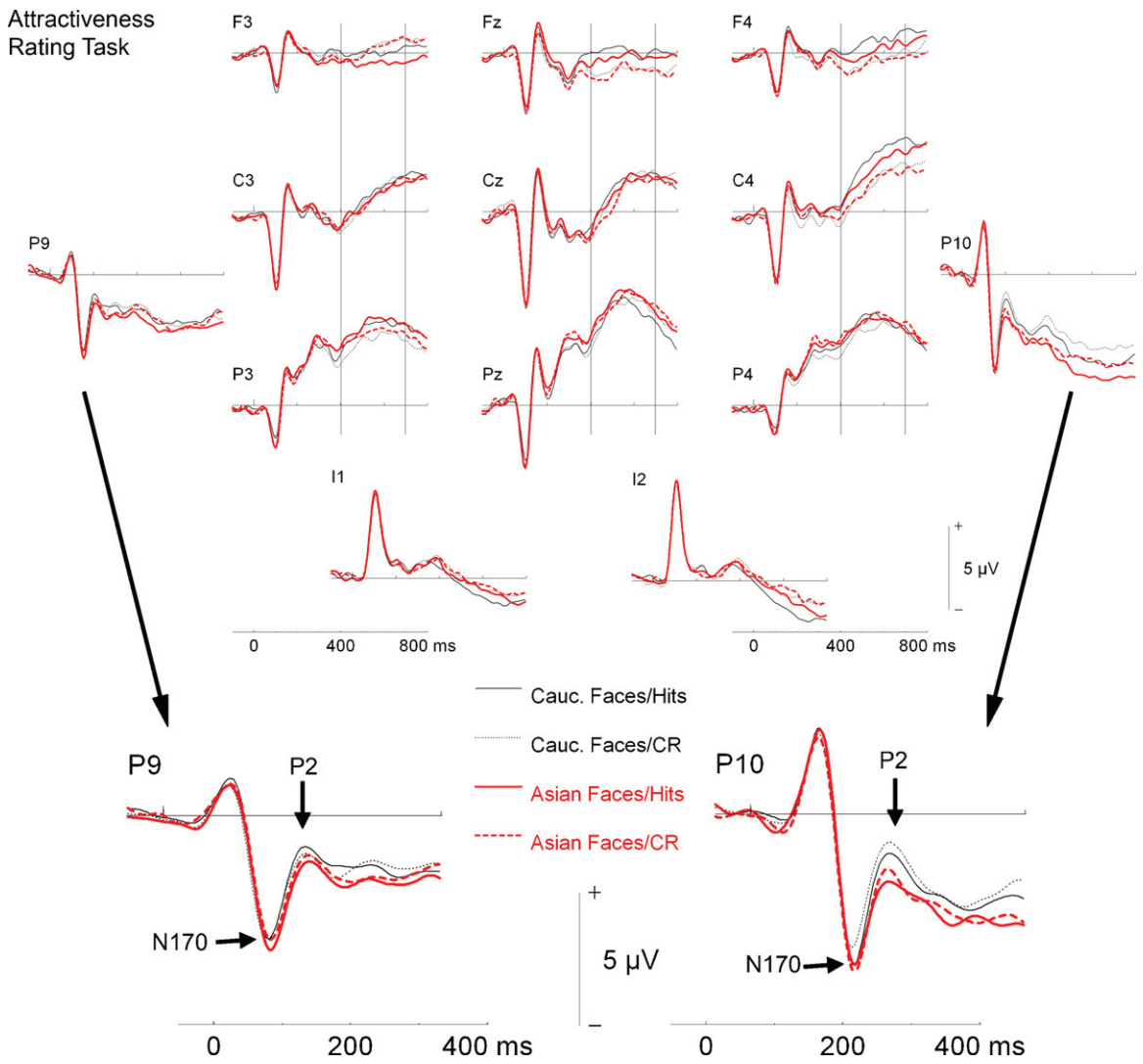

Fig. 4. Grand Mean waveforms for Asian and Caucasian faces during test phases in the attractiveness rating group (Fig. 4). ERPs are plotted from −100 to 800 ms for all electrodes and from −50 to 400 ms for P9 and P10. Note the P2 effects of face ethnicity and learning task (as indicated by arrows).

other-race faces were treated as "out-group" faces in this condition. This is in clear contrast to the categorization condition, in which both behavioural and ERP measures clearly differed between same- and other-race faces. The finding that this differential situation in the two learning conditions did not affect the own-race recognition memory bias at test appears hard to explain within a purely socio-cognitive framework of the own-race bias that stresses perceived "out-group" membership of other-race faces as a critical factor underlying the phenomenon.

With respect to the explicit instruction in both groups to memorize all faces one might add, that any effort to memorize the faces was preceded by a speeded decision for each face. From the perspective of the race-feature theory, it thus appears plausible to assume that participants were not able to carry out these tasks independently from each other and that the first one (which was the speeded task) exerted an effect on the way the second task (memorization) was executed. More precisely, when asking participants to first attend to the ethnicity of the presented faces, this initial task might have affected the following effort to memorize each individual face. Following Levin (2000), participants do not process individuating information to the same extent once a specific face has explicitly been categorized as an "out-group" face. This deficient "individuation of out-group faces" during encoding may have not appeared in the attractiveness-rating task in which no explicit categorization was requested. As noted above, while both ERP and behavioural data support the assumption of disparate processing of same- and other-race faces in the two learning conditions despite the common instruction to memorize the faces, these different mechanisms during learning did not affect the own-race bias at test.

In contrast to the predictions derived from socio-cognitive accounts of the own-race bias, the behavioral results from the current study are well in line with an expertise-based account, as exemplified by Valentine's multidimensional face-space model (Valentine, 1991). Since participants in both groups did not possess sufficient expertise with other-race faces, their face space would be assumed to be highly specialized for own-race faces. Even if the learning task triggered more accurate processing of other-race faces, one might suggest that according to the multidimensional face-space model, this would still not allow for better recognition performance, since the dimensions of the participants' MDFS were not adequate to store highly differentiated representations of other-race faces. In other words: Although other-race faces were processed highly similarly to same-race faces in the attractiveness rating group and a comparable *amount* of facial information was extracted during study, this information was not as beneficial to

other- as compared to own-race face recognition at test. This is because the non-expert participants examined in the present study extracted the same *type* of information from own- and other-race faces, which may be highly diagnostic for own-race face recognition but not to the same extent for other-race recognition, since the facial dimensions of maximal variation may be different ones for Asian than for Caucasian faces. Thus, no behavioural differences between the two learning conditions were detected at test for other-race faces.

Expertise-dependent adaptation of the MDFS is assumed to be a long-term developmental process (Walker & Hewstone, 2006; for empirical support, see Chance, Turner, & Goldstein, 1982). In line with this, re-analysis of a recent study from our lab (Stahl et al., 2008) confirmed an effect of expertise on the own-race bias, with other-race experts ($M = -0.10$, $SD = 0.11$) exhibiting a significantly lower own-race bias (d', calculated according to Macmillan & Creelman, 1991) compared to non-expert participants ($M = -0.19$, $SD = 0.12$; $z = -2.288$, $p < .05$). The present results are thus in line with the perceptual learning approach, with participants showing no decrease in their own-race bias measures following an attractiveness rating learning task, which induced attention to shift towards non-race-specifying features in both own- and other-race faces.

It should be noted that the learning tasks likely differed in difficulty, since attractiveness ratings were presumably more difficult than categorization (see RT results). Interestingly, however, this more difficult task did not affect recognition memory performance at test, since d' for both Caucasian and Asian faces did not differ between groups. In light of these findings, one might argue that our learning tasks simply were unsuited to elicit any differential effect in the test phases. This interpretation, however, is in contradiction with the present ERP results (detailed below), which did show differential ERP effects for own- and other-race faces depending on the learning tasks, in both learning and test phases.

The present findings are generally in line with a very recent study with a similar paradigm (Rhodes, Locke, Ewing, & Evangelista, 2009). In that study, several learning tasks in a recognition memory test were compared regarding their effect on the own-race bias. Tasks that explicitly required participants to process the ethnicity of a given face (either by categorizing faces according to their ethnicity or by rating the ethnic typicality of any given face in the learning phases) elicited a clear own-race bias. To the contrary, participants who were informed about the nature of the own-race bias, and who were encouraged to individuate own- and other-race faces, did not exhibit an own-race bias. In addition, a task in which participants were required to rate the attractiveness of faces in the learning phase produced a larger own-race bias than the race-coding conditions described above, since participants in this condition were selectively better at recognizing own-race, but not other-race faces. The latter finding is in line with the results from the current study, in which numerically (although not significantly) larger d'-measures were recorded under the attractiveness rating task condition for Caucasian faces.

Further support for the perceptual learning account can be derived from a recent study in which participants were extensively trained to differentiate other-race faces at either an individual or a categorical level (Tanaka & Pierce, 2009). Following several training sessions on different days, participants demonstrated better recognition performance only for other-race faces that were learned at an individual level, but not for those that were learned categorically. Taken together, these findings suggest that, unless participants are either trained extensively to individuate other-race faces or explicitly warned of the own-race bias (which may result in a voluntary and strategic allocation of enhanced attentional resources to other-race compared to own-race faces), a modulation of the learning task per se is unlikely to influence the own-race bias in performance.

With regard to ERP results, the present study yielded evidence for task-dependent ERP-modulations as well as further support for the influence of face ethnicity on several ERP-components associated with face processing. These findings are discussed separately for each of the analyzed components below.

4.2. P1

Analysis of P1 amplitude revealed an interaction of 'hemisphere × face ethnicity' as well as a main effect of 'group' during learning. While the finding involving the face ethnicity factor has to be interpreted with caution, since slight variations in low-level stimulus characteristics between conditions may well have elicited this effect (for a related discussion, see Jacques & Rossion, 2006), the main effect of 'group' with enhanced P1 amplitudes in the categorization compared to the attractiveness rating group is unlikely due to such low-level effects, since stimuli in the different learning tasks were balanced across participants. To our knowledge, only one previous study on face processing directly tested the influence of task on the P1 and found increased amplitudes in a recognition task as compared to a gender discrimination task (Rossion, Campanella et al., 1999). The authors attributed their finding to differences in arousal and attention, an interpretation which is well in line with previous research on factors influencing P1 (Hillyard et al., 1998; see also Taylor, 2002). We thus hypothesize the task effect in the present study to be due to attentional differences during early visual processing between the learning tasks. Since this interpretation is post hoc and thus somewhat speculative, future research is needed to better understand potential effects of task on P1 amplitude.

4.3. N170

We demonstrated a clear effect of face ethnicity on the N170 ERP component, which was independent of the learning condition. In both the learning and test phases, N170 to Asian faces was significantly delayed when compared to Caucasian faces, with additionally more negative N170 amplitudes to Asian faces in the test phases. These results are consistent with N170 latency (Stahl et al., 2008; Wiese et al., 2009) and amplitude effects observed in prior studies (Stahl et al., 2008). More specifically, the N170 latency delay for other-race faces appears to be a stimulus-dependent effect, which has been consistently found in our earlier studies on other-race face processing, but not for other-age face recognition (Wiese et al., 2008). In addition, the present differences in N170 amplitude replicate earlier findings of N170 amplitude differences for own- and other-race faces (Stahl et al., 2008). Taken together, these results from the current and earlier studies may indicate that N170, which has been suggested to represent early structural encoding of faces, is sensitive to the ethnicity of a given face in recognition memory paradigms, but is not affected by long-term expertise with other-race faces or differential processing of faces as triggered by manipulations of the learning task.

4.4. P2

Of particular importance, the earliest influence of learning condition on ethnicity-dependent ERP differences was observed in a subsequent P2 component. During the learning phases, ethnicity-dependent differences in P2 mean amplitudes were significant only in the categorization group, whereas no such differences were found in the attractiveness rating group. Furthermore, analysis of P2 mean amplitudes for the test phases showed clear amplitude dif-

ferences in the categorization group over both hemispheres. In the attractiveness rating group, ethnicity-dependent amplitude differences were only visible over the right hemisphere, but not over the left hemisphere. These findings have implications on several aspects.

First, participants in the categorization group exhibited similar ERP responses at test as the control group in a prior study (Stahl et al., 2008). Secondly and more importantly, the variation of the learning task in the attractiveness rating group apparently triggered recognition mechanisms similar to the reduced P2 effects exhibited by the experts in Stahl et al. (2008), speaking for more expert-like processing of own- and other-race faces in participants recruited from the same population as the control group in the former study. These patterns speak for a successful manipulation of other-race face processing which is highly similar to the processing of own-race faces during learning in the attractiveness rating group. Importantly, it appears that the learning task also affected own- and other-race face processing at test, with more similar processing to be found in the P2 component in the attractiveness rating group. These findings might therefore argue for a similar analysis of own- and other-race faces in the attractiveness rating group, but not in the categorization group.

However, even though participants in the attractiveness rating group exhibited somewhat expert-like electrophysiological processes over the left as opposed to the right hemisphere, the own-race bias was not affected by these modulations. The P2 has been suggested to represent second-order configural processing (Latinus & Taylor, 2006), which may be important for recognizing faces. In the current study, similar P2 effects were found in both learning and test phases. This might be interpreted as showing that participants in the attractiveness rating group processed Asian and Caucasian faces at the processing stage reflected by P2 in a comparable manner both in the learning and test phases. However, not only the amount of extracted second-order configural information might have been similar for Asian and Caucasian faces, but also the exact type of information. This information in turn may have been well suited for own-race face recognition, but may have not differentiated ideally between other-race faces. Thus enhanced second-order configural processing in the attractiveness rating group did not affect recognition memory performance for other-race faces at test.

As noted above, in our previous study, experts for Asian faces exhibited a significantly lowered own-race bias compared to a control group and also showed similar processing for own- and other-race faces in the P2 component. However, in contrast to the participants of the present study, experts may have extracted diagnostically highly relevant configural information for both Asian and Caucasian faces, which presumably differs for the two ethnic groups. This different type of information derived from other-race faces may have led to the smaller own-race bias observed in this group. A possible interpretation of those findings is that long-term expertise acquired during extensive training, rather than just a short-term influence of processing strategy, is necessary to affect the behavioral own-race bias.

Finally, it should be noted that we did not test for task effects on faces that were independent of the learned set, and thus the present experiment was not designed to distinguish between category-specific or image-specific learning. In the current study we were mainly interested in study task effects on recognition memory performance. However, P2 effects in the test phases did not differ between hits and correct rejections in both groups, while the presence or absence of face ethnicity effects were similar to those observed in the learning phases. It could thus be argued that participants in the categorization and attractiveness rating groups processed face stimuli similarly in the study and test phases, independent of whether or not the particular faces were presented during study. This pattern of results argues against a purely image-specific interpretation for our findings in the P2 at test, but instead suggests that the same mechanisms are applied to learned and new stimuli.

4.5. Old/new effect

Analysis of the old/new-effect revealed an interaction of response and face ethnicity in the attractiveness rating group, indicating a greater Old/New-Effect for own-race compared to other-race faces. However, this interaction did not occur in the categorization group. In accordance to the current results, a recent study on the own-age bias in a group of young and elderly participants (Wiese et al., 2008) found an interaction of face age and response in the ERPs of young participants only, indicating enhanced old/new effects for young faces as compared to old faces. These results were in line with a behavioural own-age bias in the young, but not the elderly participants. Wiese et al. interpreted this old/new effect to reflect a differential amount of retrieved information when recognizing young and old faces, which is in line with empirical evidence suggesting that the parietal old/new effect is sensitive to the amount of information recollected from episodic memory (Vilberg et al., 2006). Moreover, as demonstrated by Meissner, Brigham, and Butz (2005), the own-race bias can also be linked to the fact that humans normally encode more detailed information about own-race faces as compared to other-race faces. Following that line of thought, the nature of the present Old/New-Effects can be interpreted in the same fashion, with a greater Old/New-Effect for Caucasian faces in the attractiveness rating group indicating a larger amount of recollected information for correctly recalled own-race faces.

5. Conclusion

In sum, the present study clearly demonstrates an influence of the learning task on electrophysiological correlates of own- and other-race face perception and memory in two groups of non-experts regarding other-race faces. Although a behavioural own-race bias was clearly evident in both groups and did not differ between groups, ERPs to own- and other-race faces showed a strikingly different picture, with generally enhanced N170 amplitudes to other-race faces as well as clear effects of ethnicity on the P2 and LPC components in the categorization but not in the attractiveness rating group during learning. We therefore assume that highly similar encoding mechanisms to own- and other-race faces were not sufficient to elicit a lower own-race bias, since our participants' multidimensional face space was not suited to adequately store other-race faces. According to these observations, we assume that although manipulating the learning task in a recognition memory experiment clearly modulates perceptual processing of own- and other-race faces, such a manipulation is not sufficient to attenuate or eliminate the behavioural own-race memory bias. Instead, long-term perceptual expertise with other-race individuals appears to be a necessary precondition for improved other-race face recognition.

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Abstract: People are generally better at recognizing faces from their own ethnic group as compared to faces from another ethnicity. This so-called own-race bias has been attributed to perceptual learning and lifetime expertise with faces of one´s own ethnicity. The current study aimed at creating expertise with other-race faces by training naïve Caucasian participants to individuate own-race (Caucasian) and other-race (Asian) faces. Following extensive multi-session training, a comparison of recognition performance for own- and other-race faces indicated a general attenuation of the own-race bias from pre-training to post-training, which was largely due to decreased recognition performance for Caucasian faces. Furthermore, event-related potentials to own- and other-race faces revealed effects of training on early components. Whereas N170 was initially delayed and increased to Asian faces over the left hemisphere, individuation training induced a general decrease in N170 latency and a shift of ethnicity-dependent N170 effects to the right hemisphere. More importantly, specific and ethnicity-dependent effects of training were evident in the occipito-temporal P2 component, which was initially larger to Caucasian than to Asian faces. After training, this P2 amplitude difference between Caucasian and Asian faces disappeared over the left hemisphere. Thus, training induced more similar processing of own- and other-race faces, but did not enhance those mechanisms specifically relevant for the correct recognition of other-race faces.

1. Cover Letter

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Dear Editors of Brain Research,

Please find attached a manuscript “Effects of Training on ERP-correlates of the Own-Race Bias in Face Recognition” for possible publication in Brain Research under the section “Cognitive and Behavioral Neuroscience”.

In this manuscript, we present novel research on electrophysiological correlates of the effects of individuation training on the own-race bias in face memory – the observation that people remember own-race faces more accurately than other-race faces. We describe an experimental training design, in which naïve Caucasian participants first completed a recognition memory experiment with Asian and Caucasian face stimuli to assess a baseline of the own-race bias. Subsequently, participants attended five training sessions, in which they learned to individuate and memorize a total of 40 Asian and 40 Caucasian individuals. Finally, participants attended a second recognition memory experiment on a new set of Asian and Caucasian faces to test for a generalized training effect on the own-race bias. Comparison of the recognition tests showed a reduction of the own-race bias in the post-training as compared to the pre-training test. This reduction was however, not due to increased recognition accuracy to other-race (Asian) faces, but to decreased recognition performance to own-race (Caucasian) faces. Furthermore, analysis of ERP recordings from the pre- and post-training recognition test showed an interaction of ethnicity and training effects in early ERP components. Whereas N170 was initially delayed and increased to Asian faces over the left hemisphere, individuation training induced a general decrease in N170 latency and a shift of ethnicity-dependent N170 effects to the right hemisphere. More importantly, specific and ethnicity-dependent effects of training were evident in the occipito-temporal P2 component, which was initially larger to Caucasian than to Asian faces. After training, this P2 amplitude difference between Caucasian and Asian faces disappeared over the left hemisphere. Thus, training induced more similar processing of own- and other-race faces, but did not enhance those mechanisms specifically relevant for the correct recognition of other-race faces.
We discuss our observations in relation to other recent findings on ERP correlates of the own-race bias by others and ourselves, and suggest a perceptual learning account for the phenomenon. We believe that our results are highly relevant not only for the fields of social cognition and cognitive neuroscience, but also for current theories of how faces are mentally represented for recognition.

To the best of our knowledge, the manuscript describes the first ERP study on the influence of training on the recognition of own- and other-race faces and its effect on

the own-race bias. Thus, our results should be of interest to researchers working in related fields and to the readers of Brain Research. We would greatly appreciate a consideration for publication of our manuscript.

Yours sincerely,

Johanna Stahl

***2. Suggested Reviewers**

seit 1558

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Dear Editors of Brain Research,

we kindly suggest the following reviewers for peer review of our manuscript “Effects of Training on ERP-correlates of the Own-Race Bias in Face Recognition” for possible publication in Brain Research:

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Effects of Training on ERP-correlates of the Own-Race Bias in Face Recognition

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Short title: Training and the Own-Race Bias

Abstract

People are generally better at recognizing faces from their own ethnic group as compared to faces from another ethnicity. This so-called own-race bias has been attributed to perceptual learning and lifetime expertise with faces of one´s own ethnicity. The current study aimed at creating expertise with other-race faces by training naïve Caucasian participants to individuate own-race (Caucasian) and other-race (Asian) faces. Following extensive multi-session training, a comparison of recognition performance for own- and other-race faces indicated a general attenuation of the own-race bias from pre-training to post-training, which was largely due to decreased recognition performance for Caucasian faces. Furthermore, event-related potentials to own- and other-race faces revealed effects of training on early components. Whereas N170 was initially delayed and increased to Asian faces over the left hemisphere, individuation training induced a general decrease in N170 latency and a shift of ethnicity-dependent N170 effects to the right hemisphere. More importantly, specific and ethnicity-dependent effects of training were evident in the occipito-temporal P2 component, which was initially larger to Caucasian than to Asian faces. After training, this P2 amplitude difference between Caucasian and Asian faces disappeared over the left hemisphere. Thus, training induced more similar processing of own- and other-race faces, but did not enhance those mechanisms specifically relevant for the correct recognition of other-race faces.

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1. Introduction

Recognizing faces of another ethnicity is often experienced to be considerably harder than recognizing faces from one's own ethnic group (Brigham & Barkowitz, 1978). This so-called own-race bias is a well-documented phenomenon in the area of face recognition memory (Meissner & Brigham, 2001). Despite this own-race advantage in *recognition*, there is typically a disadvantage for own-race faces in tasks of ethnicity *classification*, meaning that own-race faces are usually classified more slowly as belonging to a certain ethnicity than other-race faces (Valentine & Endo, 1992). Whereas several theories have been put forward to account for this effect from a socio-cognitive perspective (Levin, 1996), empirical evidence has also been pointing towards a contribution of long-term perceptual learning and relatively increased expertise with the participants' own ethnic group as compared to a different ethnic group as the basis of the own-race bias.

More specifically, the multidimensional face-space (MDFS) model by Valentine (1991) suggests that the representation of a given face can be understood as a point on multiple perceptual dimensions, which reflect the physiognomic characteristics of faces. It is further hypothesized that these dimensions evolve due to a person's lifetime experience with faces and develop in a way as to optimally discriminate between individual faces. Since most people acquire face expertise in ethnically homogenous environments, their MDFS relies on dimensions that best serve to discriminate between faces from the individual's own ethnic group. Hence, experience with primarily the person's own ethnicity results in a MDFS that is highly specialized towards that specific ethnic group. This in turn leads to decreased correct recognitions as well as increased false positives when memory for faces from another ethnic group is compared to memory for faces from the individual's own ethnicity (Valentine & Endo, 1992).

Empirical evidence for the perceptual expertise account comes from three lines of research. First, several studies were able to show that the own-race bias evolves and increases

with age from childhood to adulthood (Chance et al., 1982; Walker & Hewstone, 2006) and that children adopted into a cross-ethnic environment may show an abolished (de Heering et al., 2010) or even reversed own-race bias (Sangrigoli et al., 2005). Secondly, the own-race bias has been shown to be weakened in individuals with sufficient expertise for other-race faces (Chiroro & Valentine, 1995; Hancock & Rhodes, 2008). Thirdly, studies using auto-associative networks trained on a majority and a minority race of faces were able to demonstrate that these networks will only exhibit response patterns mimicking the own-race bias in humans when they are tuned to optimally encode individuating information between individual faces of the majority race of faces (O'Toole et al., 1991; Furl et al., 2002). The latter findings were interpreted as demonstrating perceptual tuning of the face recognition system to information that is useful specifically for processing own-race faces, and such tuning therefore limits the quality of representations of other-race faces.

In addition to this reduced quality of *representation* for other-race faces, several face *processing* stages may be affected differentially by the ethnicity of a given face. Face recognition has been assumed to involve both featural and configural processing. Featural processing is assumed to reflect piece-meal analysis of isolated face parts (such as the eyes, the nose etc.). By contrast, configural processing of faces is concerned with spatial relations between such features and has been further divided into three sub-phases (Maurer et al., 2002) – first-order configural processing, i.e. the detection of features in a broadly face-like spatial configuration (two eyes above a nose above a mouth), holistic processing, i.e. merging the different facial features into a whole or gestalt, and second-order configural processing, i.e. perceiving the spatial distances between the different features. The use of configural information seems to be associated with the degree of expertise for a given class of faces (Rhodes et al., 1989). Thus, over the course of several experiments it has been demonstrated that own-race faces are processed more holistically than other-race faces (Tanaka et al., 2004; Michel et al., 2006). In that regard, explanations of the own-race bias in terms of enhanced

configural processing of own-race faces can also be viewed as being expertise-based. Additionally, these findings have been extended by demonstrating that not only configural, but also featural coding seem to be enhanced for own-race compared to other-race faces (Rhodes et al., 2006).

Also in line with an expertise-based account of the own-race bias, training expertise for other-race faces has been shown to enhance recognition performance to such faces (Goldstein & Chance, 1985; Lebrecht et al., 2009). Moreover, a recent study (Tanaka & Pierce, 2009) provided empirical evidence for a differential benefit of basic- and subordinate-level training in recognition performance for other-race faces. Specifically, intensive subordinate-level (individuation) training with other-race faces from one ethnicity (e.g., for Caucasian participants, *either* Hispanic or African American faces) over a course of five training sessions led to an improvement in recognition accuracy for this specifically trained face ethnicity, whereas basic-level (categorization) training on other-race faces from another ethnicity (e.g., *either* African American or Hispanic) did not. Overall, and in line with both of the discussed expertise-based accounts, the own-race bias appears to decrease both as a result of long-term perceptual expertise with other-race faces and as a result of intensive individuation training.

In contrast to the expertise-based accounts described above, a number of other studies stress the role of situational context and socio-cognitive processes. Accordingly, the own-race bias has been reported to be affected by "mere" social categorization of a person as an ingroup or outgroup member (Bernstein et al., 2007; Shriver et al., 2008), the perception of an ethnically ambiguous face as an own- or other-race face (Michel et al., 2007; but see Rhodes et al., 2010), accessibility of encoding context memory (Horry & Wright, 2008), informing participants about the phenomenon of the own-race bias itself (Hugenberg et al., 2007; Rhodes et al., 2009b) and emotional expression (Johnson & Fredrickson, 2005). The presumably most prominent socio-cognitive account, the race-feature hypothesis by Levin

(1996) assumes a mechanism in which the detection of an other-race-specifying feature in a given face (such as dark skin color in African or African-American faces for a Caucasian participant) leads to inferior processing, which is primarily concerned with analyzing isolated category-defining visual features rather than processing individuating facial information (Levin, 2000). By contrast, own-race faces are suggested to be processed at an individual level, leading to relatively enhanced recognition memory. In summary, reports of situational influences on the own-race bias strongly contrast with explanations of the phenomenon derived from the expertise-based models described above. A "pure" situational or socio-cognitive account of the own-race bias would predict no effects of experience on the own-race bias, and thus the effect should not change with training.

The present study aimed at examining the effect of acquisition of expertise by training naïve participants to individuate own- and other-race faces. During extensive training over a number of sessions, participants learned to recognize both own- and other-race faces until perfect recognition accuracy was achieved for all individual faces. By comparing pre- and post-training measures of the own-race bias, effects of training on face recognition performance were analyzed. Importantly, and in contrast to previous studies (Tanaka & Pierce, 2009; Lebrecht et al., 2009), the aim of the present study was to test whether effects of individuation training on both own- and other-race faces would generalize to increased recognition memory performance for novel other-race exemplars. Thus, recognition memory performance in pre- and post-training assessment was measured with two different stimulus sets, thereby testing for a generalization of training on recognition accuracy to faces form the observer's own (Caucasian) and another (Asian) ethnicity.

Electrophysiological correlates

In contrast to the behavioral experiments on the own-race bias described above, which can only measure the outcome of face processing mechanisms, electrophysiological methods

such as event-related potentials (ERPs) allow for detailed chronometric assessment of the neural mechanisms that mediate different processing stages in face perception and memory (Rugg & Coles, 1995; Bentin et al., 1996). ERPs may therefore be an essential aide in bringing to light the underlying mechanisms of own- and other-race face processing.

The earliest ERP component relevant for the present study is the P1, a positive deflection over occipital areas, which usually peaks at around 100 ms after the onset of a visual stimulus. The P1 has been reported to be sensitive to basic stimulus properties, such as contrast, luminance and spatial frequency (Schendan et al., 1998). P1 has therefore been assumed to reflect early visual processing (Luck, 2005), although this component also is modulated by spatial attention (Hillyard et al., 1998) and arousal (Vogel & Luck, 2000).

Subsequent to the P1, the N170 is characterized by a negative deflection maximal over right occipito-temporal sites (Bentin et al., 1996; but also see Rossion et al., 1999 and Bentin & Deouell, 2000). N170 has been demonstrated to be more pronounced for human faces as compared to object stimuli and has been interpreted to reflect structural encoding of faces (Eimer, 2000b). However, two opposing theories have been put forward to account for this effect. While some argue for domain specificity of the N170 solely to human faces (e.g. Carmel & Bentin, 2002), others suggest the N170 to be a marker for expertise with a given stimulus class (Tanaka & Curran, 2001; Rossion et al., 2002). Several studies, which were interpreted to support the latter account, reported face-like N170 ERP responses in experts for non-face stimuli (Tanaka & Curran, 2001) and after extensive subordinate-level training with objects (Scott et al., 2008), natural stimuli (Scott et al., 2006) or complex artificial stimuli (Rossion et al., 2002).

N170 has also been shown to be influenced by inversion of faces, such that inverted faces resulted in a larger and delayed N170 compared to upright faces (e.g. Eimer, 2000a; Itier & Taylor, 2002; Itier & Taylor, 2004). It is commonly assumed that inversion disrupts configural and holistic processing (Maurer et al., 2002), which has also been shown to be

larger for own-race as compared to other-race faces (see paragraphs above). However, evidence for the influence of face ethnicity on N170 remains mixed. Whereas some studies did not detect any ethnicity-dependent N170-modulations at all (James et al., 2001; Caldara et al., 2004), other studies showed larger amplitudes to own- as compared to other-race faces in the N170 time range. The latter effects did, however, appear at atypical N170 locations (Caldara et al., 2003) or with atypical reference settings (Ito & Urland, 2005). More recently, several studies reported *smaller* N170 amplitudes to own-race faces compared with other-race faces (Herrmann et al., 2007; Walker et al., 2008), an effect that has also been found to be accompanied by delayed latencies for other-race as compared to own-race faces (Stahl et al., 2008; Stahl et al., 2010). In addition, it has been observed that this N170 effect did not differ between participants with and without specific expertise in regard to other-race faces (Stahl et al., 2008). Thus, the N170 may not be susceptible to varying degrees of expertise with other-race faces.

Even though the reason for these discrepant findings on N170 ethnicity effects remains unclear, it appears plausible that some of these discrepancies are due to the different experimental tasks used in the studies mentioned above. Whereas most of the earlier studies used categorization or passive viewing tasks, the latter experiments that observed smaller N170 amplitudes for same- as compared to other-race faces adopted tasks which explicitly required participants to process faces for identity. In line with this interpretation, a recent ERP study on the effects of face inversion and ethnicity that used an orientation judgment task demonstrated a delayed but not increased N170 to other-race faces, an effect which was observed independent of, and in addition to the well-known N170 effects caused by face inversion (Wiese et al., 2009; but see Vizioli et al., 2010). Importantly, the stimuli used in this study were largely identical to those used in our previous experiments (Stahl et al., 2008; Stahl et al., 2010), in which ethnicity effects on N170 amplitude were detected. Taken together, these recent studies indicate that N170 may be sensitive to the ethnicity of a given

face in recognition memory paradigms, but not in a simple orientation judgment task. Finally, a recent study on effects of training on ERP correlates of other-race face recognition observed earlier N170 peaks following training as compared to a pre-training baseline (Tanaka & Pierce, 2009). This latency decrement was not affected by the kind of training (i.e., categorization training vs. individuation training) participants were subjected to. The authors therefore interpreted this N170 latency decrement to reflect facilitated structural encoding after intensive perceptual training on faces.

Following N170, the occipito-temporal P2 has gained increasing attention over the last years. It is characterized by a positive-going deflection over lateral occipito-temporal scalp areas and reaches a maximal peak between 200 and 250 ms following stimulus onset. This P2 component has been found to be larger to photographic as compared to half-tone Mooney faces (Latinus & Taylor, 2006), to normal as compared to Thatcherized faces (Milivojevic et al., 2003) and to normal as compared to spatially distorted faces (Halit et al., 2000). As a result from these observations, the P2 has been linked to the processing of spatial relations between facial features in individual faces (Latinus & Taylor, 2006). In a recent experiment, participants were asked to judge whether two subsequently presented images differed with respect to feature or configuration information (Mercure et al., 2008). In line with earlier findings, P2 was observed to be more positive to configurally altered faces.

In addition to these findings, recent studies showed larger P2 amplitudes to young as compared to old faces (Wiese et al., 2008) and to own- versus other-race faces (Stahl et al., 2008; Stahl et al., 2010) in young, Caucasian participants. Furthermore, the latter experiments showed that the difference in P2 for own- versus other-race faces was found to be reduced both in participants with long-term expertise for other-race faces (Stahl et al., 2008), and in a task that necessitated deep encoding of both own- and other-race faces during learning (Stahl et al., 2010). Taken together, the P2 component may be interpreted as being sensitive to second-order configural processing and the perceived typicality of stimuli relative to a face

prototype. In addition, P2 amplitude can be modulated by expertise with out-group faces and specific task demands.

The subsequent N250 component has been linked to the activation of structural face representations (Schweinberger & Burton, 2003). This component exhibited more negative amplitudes to immediately repeated compared to novel faces over right occipito-temporal regions in a time range of 200 to 350 ms (Schweinberger et al., 1995; Begleiter et al., 1995). This so-called N250r effect ("r" for repetition) has been demonstrated to be more pronounced for familiar as compared to unfamiliar faces (Pfutze et al., 2002; Herzmann et al., 2004). Itier and Taylor (2004) found delayed N250r effects for inverted and contrast-reversed faces, which was interpreted as reflecting more difficult access to representations of configurally altered faces. However, repeatedly presenting own- and other-race faces showed no differential repetition effects in this component (Herrmann et al., 2007). In addition, it was reported that an N250 component with similar topography is also sensitive to longer term acquisition of face representations, and has been shown to increase over time during learning pre-experimentally unfamiliar faces (Tanaka et al., 2006; Kaufmann et al., 2009). Of particular importance for the present experiment, a previous study reported increased N250 amplitudes as a result of individuation training, but not following categorization training for other-race faces (Tanaka & Pierce, 2009).

Finally, a late positive complex (LPC) characterized by a positive deflection peaking around 400 ms after stimulus onset has been shown to be larger for own-race than other-race faces (Ito & Urland, 2003). Additionally, stimuli learned in recognition memory experiments ("old" stimuli) elicited more positive amplitudes than new stimuli in the time range of approximately 400-700 ms after stimulus onset. This old/new effect has been shown to be maximal over left parietal electrodes for word stimuli (Rugg & Curran, 2007) and has been related to the conscious recollection of episodic memory or, more specifically, to the amount of recollected information (Vilberg et al., 2006). In addition to the literature on verbal

memory, more positive amplitudes were also recorded for learned as compared to new faces (Paller et al., 2000; Paller et al., 2003). In a very recent study, it has also been demonstrated that the scalp distribution of the old/new-effect differs depending on the stimulus material (Yick & Wilding, 2008), with a more widely distributed old/new-effect for faces as compared to words and a more anterior scalp distribution of the old/new-effect to faces (MacKenzie & Donaldson, 2009).

The present study

In the present study, we aimed at investigating the effect of training on the own-race bias and electrophysiological correlates of own- and other-race face processing. Thus, Caucasian participants engaged in intensive individuation and recognition training with own-race (Caucasian) and other-race (Asian) faces. If such training were to induce substantial perceptual expertise, the behavioral own-race bias would be expected to be reduced following individuation training – a hypothesis supported by the findings of Tanaka and Pierce (2009). If, however, expertise were exclusively the result of long-term perceptual learning, intensive training over the relatively short time span of several sessions might not suffice to significantly affect the behavioral own-race bias. In contrast to the training study conducted by Tanaka & Pierce (2009), participants in the current study completed training on both own- and other-race faces. Even in this situation, we expected that training would differentially affect own- and other-race face recognition performance (Malpass, 1981). More specifically, in light of expertise-based explanations of the own-race bias it appears reasonable that Caucasian participants have already accumulated a massive amount of expertise with own-race faces over their life-time. Hence, individuation training with own-race faces should have little to no effect on recognition memory performance. In line with this, Sporer (1991, p. 330) noted that one "should not wonder too much that practically all training programs that have attempted to improve facial recognition have failed, at least with regard to own-race faces",

an observation that is backed by other work (for a review, see Malpass, 1981). In contrast, sufficient and successful individuation training with other-race faces should increase recognition memory performance for these stimuli.

With regard to ERP correlates of own- and other-race face processing, and similar to the results of our previous studies, we expected enhanced N170 amplitudes and delayed N170 latencies to other-race as compared to own-race faces, but no interaction between training effects and ethnicity-dependent modulations of the N170. Furthermore, the occipito-temporal P2 has been shown to differentiate between experts and non-experts for other-race faces (Stahl et al., 2008). We hypothesized that individuation training with own- and other-race faces might have a similar effect on the P2. Therefore, we expected P2 effects similar to those observed in non-experts prior to training, whereas P2 effects similar to those observed in experts were hypothesized post-training (Stahl et al., 2008).

The N250 has been shown to increase over time during the learning of novel faces (Tanaka et al., 2006; Kaufmann et al., 2009), and delayed N250r effects for inverted and contrast-reversed faces were interpreted as representing more difficult access to representations of faces when configural processing was disturbed (Itier & Taylor, 2004). One could therefore hypothesize that other-race faces, which have been shown to differ from own-race faces in regard to featural and configural processing (Rhodes et al., 2006), may evoke a decreased N250 effect for learned as compared to novel faces in recognition memory experiments, since representations of own-race faces are possibly easier to access than representations of other-race faces. At the same time, individuation training might result in an increased N250 learning effect for other-race faces. Finally, we wanted to test for effects of training and ethnicity on the LPC and Old/New-effect. If training resulted in more individual level processing of own- and other-race faces, we would expect retrieval of more detailed information about individual faces and therefore a more pronounced Old/New-effect following intensive training.

Thus, in order to assess the influence of training on the own-race bias, participants in the current study completed two recognition memory tests on two different sets of own- and other-race faces before and subsequent to five intensive face individuation training sessions (please refer to Figure 1 for a schematic representation of experimental sessions). During the learning phases in both pre- and post-training recognition memory tests, participants had to categorize faces according to ethnicity. In subsequent test phases, participants were required to differentiate learned ("old") from novel ("new") faces. During both pre- and post-training tests, 32-channel-EEG was recorded, and ERPs were computed and analyzed for effects of face ethnicity and training.

- enter Figure 1 about here -

2. Results

Behavioural results

Learning phases: No statistical analysis was performed on accuracy, since performance levels were near ceiling: During learning in pre-training assessment, participants correctly categorized 96% of Caucasian and 99% of Asian faces. Following training, accuracies in the ethnicity categorization task during learning amounted to 97 % for both Asian and Caucasian faces.

- enter Table 1 about here -

Mean correct reaction times (cf. Table 1) from the learning phases in pre- and post-training tests were analysed by computing a repeated-measures ANOVA with the factors "pre- vs. post-training" and "face ethnicity", which yielded significant main effects of "pre- vs. post-training" ($F[1,19]=6.12$, $p<.05$) and "face ethnicity" ($F[1,19]=6.47$, $p<.05$), reflecting

shorter reaction times both following training (t[19]=2.47, p<.05) and for Asian faces (t[19]=-2.54, p<.05), but no significant interaction (F<1).

Test phases: Reaction times for correct responses (see Table 1) were analysed by using a repeated-measures ANOVA with the within-subject factors "pre- vs. post-training", "face ethnicity" (Asian vs. Caucasian) and "response" (hits, Correct Rejections - CR), which resulted in significant main effects for "pre- vs. post-training" (F[1,19]=7.13, p<.05), "ethnicity" (F[1,198]=24.62, p<.001) and "response" (F[1,19]=14.53, p<.001), but no significant interactions (all p>.05). Data inspection showed that RTs were significantly faster following training, when processing Caucasian faces compared with Asian faces and to hits compared with CRs.

Correct responses from the test phases to old and new faces (hit- and correct rejection rates) were analysed by using repeated-measures ANOVA with the within-subject factors "pre- vs. post-training", "face ethnicity" and "response" (hits vs. Correct Rejections). This analysis yielded significant main effects of "face ethnicity" (F[1,19]=83.17, p<.001) and "response" (F[1,19]=11.30, p<.05) as well as the significant interaction "pre- vs. post-training x face ethnicity x response" (F[1,19]=13.92, p<.001). Subsequent analyses were carried out separately for each face ethnicity. Whereas an ANOVA of responses to hits and CRs with Caucasian faces resulted in a main effect of "response" (F[1,19]=8.33, p<.05), indicating a higher rate of CR as opposed to hits, a corresponding ANOVA for Asian faces resulted in a main effect of "response" (F[1,19]=11.69, p<.05) and a significant interaction of "response x pre- vs. post-training" (F[1,19]=9.59, p<.05). Post hoc t-tests showed both a significant reduction in hit rates (t[19]=2.24, p<.05) as well as a significant increase in CR-rates (t[19]=-2,87, p<.05) to Asian faces as a result of training.

Analysis of d' and response criterion (C) was performed by calculating Wilcoxon-Tests for comparisons of effects of ethnicity and pre- vs. post-training. Comparison of d'

between pre- and post-training assessment (cf. Table 1) demonstrated significant reductions in d' to Caucasian (z =-2.838, p<.05). By contrast, the small numerical increase in d' for Asian faces was not significant (z =-1.409, p>.05) following training. Likewise, comparison of own-race bias indices revealed significant differences between pre- and post-training assessment, indicating a lower own-race bias post training (z =-2.778, p<.05). Finally, a Wilcoxon-Test of response criterion (C) yielded significant differences between pre- and post-training assessment to Asian faces (z =-2.577, p<.05), reflecting a more conservative response criterion following training. Furthermore, this analysis also detected a trend for more liberal responses to Caucasian faces following training (z =-1.953, p=.051).

Electrophysiological results

- enter Table 2 about here -

Learning phases

P1: ANOVA of P1 latency (see Table 2) at O1 and O2 with the within-subject factors "hemisphere", "pre- vs. post-training" and "face ethnicity" revealed no significant main effects or interactions (all p>.05). An ANOVA of P1 amplitude at electrodes O1 and O2 with the same factors revealed a significant interaction of "hemisphere x pre- vs. post-training" (F[1,19]=8.74, p<.05). Subsequent comparisons for each hemisphere separately yielded no significant differences in P1 amplitudes between pre- and post-training assessment over both the left (t[19]=-0.32, p>.05) and right hemisphere (t[19]= 1.34, p>.05).

- enter Figure 2 about here -

N170: A corresponding ANOVA for N170 (cf. Table 2) latency at P9 and P10 yielded significant main effects for "hemisphere" (F[1,19]=9.94, p<.05), with later peaks over the left hemisphere, "face ethnicity" (F[1,19]=9.27, p<.05), indicating later peaks for Asian faces, and for "pre- vs. post-training" (F[1,19]=9.59, p<.05), with earlier peaks following training (cf. Fig. 2). An analysis of N170 peak amplitude at P9 and P10 revealed significant main effects of "hemisphere" (F[1,19]=13.01, p<.05) and "face ethnicity" (F[1,19]=20.76, p<.001) as well as a significant interaction of "hemisphere x face ethnicity" (F[1,19]=5.26, p<.05), indicating more negative amplitudes over the right hemisphere and an increased N170 to Asian as compared to Caucasian faces bilaterally but more pronounced over the left hemisphere (cf. Fig. 2). No interaction with the "pre- vs. post-training" factor was observed (all p>.05).

P2: An ANOVA for P2 mean amplitudes at P9 and P10 (cf. Table 2) revealed a significant main effect of "face ethnicity" (F[1,19]=74.95, p<.001) which was qualified by a significant interaction "hemisphere x face ethnicity" (F[1,19]=16.71, p<.05), but no interaction with the "pre- vs. post-training" factor (all p>.05). Further post-hoc tests confirmed significantly more positive-going mean amplitudes to Caucasian faces as compared to Asian faces over both left (t[19]=7.63, p<.001) and right hemispheres (t[19]=3.24, p<.05), with greater ethnicity-dependent amplitude differences over the left hemisphere (cf. Fig. 2).

N250: An ANOVA for N250 mean amplitudes at P9 and P10 revealed a significant main effect of "face ethnicity" (F[1,19]=64.50, p<.001) which was qualified by a significant interaction "hemisphere x face ethnicity" (F[1,19]=12.86, p<.05). Further post-hoc tests confirmed significantly more pronounced negativities to Asian faces as compared to Caucasian faces over both left (t[19]=7.59, p<.001) and right hemisphere (t[19]=2.12, p<.05), with greater ethnicity-dependent amplitude differences in the N250 over the left hemisphere. No effect of the "pre- vs. post-training" factor was observed (cf. Fig. 2).

- enter Figure 3 about here-

Late positive complex (LPC): LPC amplitudes (cf. Fig. 3) were analyzed at F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 (cf. Table 4) with the within-subject factors "face ethnicity", "pre- vs. post-training", and additional topographical factors for "anterior/posterior position" (frontal, central, parietal rows) and "laterality" (left, middle, right rows). Significant main effects for "anterior/posterior position" (F[2,38]=76.82, p<.001), "laterality" (F[2,38]=6.40, p<.05) and "face ethnicity" (F[1,19]=7.80, p<.05) were detected. These main effects were further qualified by significant interactions of "anterior/posterior position x laterality" (F[3.4,66.2]=10.11, p<.001), with more positive mean amplitudes over parietal and midline positions, and "anterior/posterior position x face ethnicity" (F[1.5,29.3]=5.60, p<.05), indicating significantly more positive mean amplitudes to Asian as compared to Caucasian faces over central (t[19]=-3.28, p<.05) and parietal (t[19]=-2.82, p<.05) recording sites. Again, no effect of the "pre- vs. post-training" factor was observed (cf. Table 4).

Test phases

- enter Table 3 about here -

P1: An ANOVA of P1 latency at O1 and O2 with the within-subject factors "hemisphere", "pre- vs. post-training", "face ethnicity" and "response" revealed a significant main effect of "face ethnicity" (F[1,19]=9.79, p<.05), indicating slightly delayed P1 peaks to Asian faces (cf. Table 3). No other main effects or interactions were significant (all p>.05). ANOVA of P1 amplitude at O1 and O2 revealed a significant interaction of "hemisphere x face ethnicity x response" (F[1,19]=8.54, p<.05). Subsequent separate ANOVAs of P1 peak amplitudes averaged across pre- and post-training assessment for each hemisphere with the

factors “face ethnicity” and “response” did not, however, yield any significant main effects or interactions (all $p>.05$).

- enter Figure 4 about here -

N170: Analysis for N170 (cf. Fig. 4) latency at P9 and P10 revealed significant main effects of “face ethnicity” ($F[1,19]=35.42$, $p<.001$), reflecting later peaks for Asian faces, and for “pre- vs. post-training” ($F[1,19]=8.63$, $p<.05$), pointing towards earlier N170 peaks following training (cf. Fig. 4). Furthermore, a significant main effect of “hemisphere” ($F[1,19]=7.50$, $p<.05$) with later peaks over the left hemisphere was detected, as well as an interaction of “pre- vs. post-training x response” ($F[1,19]=8.87$, $p<.05$). Post hoc t-tests on N170 latencies averaged across hemisphere and face ethnicity indicated significantly earlier peaks to hits as compared to CRs following training ($t[19]=-2.72$, $p<.05$), whereas no latency differences between hits and CRs ($t[19]=0.76$, $p>.05$) were observed for pre-training sessions (cf. Table 3).

Analysis of N170 amplitude at P9 and P10 yielded significant main effects of “hemisphere” ($F[1,19]=20.85$, $p<.001$), with larger amplitudes recorded over the right hemisphere, and “face ethnicity” ($F[1,19]=8.78$, $p<.05$), indicating larger amplitudes to Asian compared with Caucasian faces. Furthermore, this analysis yielded significant interactions of “hemisphere x pre- vs. post-training x face ethnicity” ($F[1,19]=4.88$, $p<.05$), “hemisphere x pre- vs. post-training x response” ($F[1,19]=4.37$, $p<.05$) and “hemisphere x face ethnicity x response” ($F[1,19]=5.37$, $p<.05$). Additionally calculated post-hoc analyses of N170 peak amplitudes averaged across hits and CRs to account for the interaction of “hemisphere x pre- vs. post-training x face ethnicity” were computed separately for each hemisphere and pre- and post-training assessment. In the pre-training assessment, these analyses confirmed a significant effect of “face ethnicity” over the left hemisphere ($F[1,19]=8.12$, $p<.05$), whereas

no significant effect of was found over the right hemisphere (F[1,19]=3.69, p>.05). In the post-training assessment, significantly more negative N170 amplitudes to Asian faces were observed over the right hemisphere (F[1,19]=6.51, p<.05), whereas this effect was absent over the left hemisphere (F<1, p>.05). To further dissect the interaction of "hemisphere x pre- vs. post-training x response", another set of ANOVAs with peak amplitudes averaged across both face ethnicities were computed separately for each hemisphere and pre- and post-training assessment, but yielded no significant differences between hits and CRs (all p>.05) Finally, for the interaction of "hemisphere x face ethnicity x response", ANOVAs of N170 peak amplitudes averaged across assessment points and computed separately for each hemisphere yielded a significant main effect of "face ethnicity" (F[1,19]=9.57, p<.05) and an interaction of "face ethnicity x response" (F[1,19]=4.51, p<.05) only over the right, but not over the left hemisphere, indicating greater N170 peak amplitudes to hits with Asian as compared to Caucasian faces (t[19]=4.22, p<.001), whereas no significant differences in N170 amplitude were measured between CRs to Asian and Caucasian faces (t[19]=1.34, p>.05).

P2: Analysis of P2 mean amplitudes (cf. Fig. 4) yielded significant main effects of "pre- vs. post-training" (F[1,19]=7.49, p<.05), "face ethnicity" (F[1,19]=16.04, p<.001) as well as significant interactions of "hemisphere x pre- vs. post-training x face ethnicity" (F[1,19]=16.12, p<.001), "hemisphere x pre- vs. post-training x response" (F[1,19]=5.05, p<.05) and "hemisphere x face ethnicity x response" (F[1,19]=4.85, p<.05). Subsequent post-hoc-ANOVAs were calculated separately for pre- and post-training assessment. To further investigate the interaction of "hemisphere x pre- vs. post-training x face ethnicity", ANOVAs on P2 mean amplitudes averaged across hits and CRs were computed for pre- and post-training sessions separately. Analysis of the pre-training session yielded a significant main effect of "face ethnicity" (F[1,19]=10.91, p<.05), indicating more positive-going P2 amplitudes to Caucasian as compared to Asian faces over both hemispheres. The same analysis for the post-training session, however, showed both a significant main effect of "face

ethnicity" (F[1,19]=7.83, p<.05) and a significant interaction of "face ethnicity x hemisphere" (F[1,19]=14.05, p<.001), indicating significantly higher amplitudes to Caucasian faces over the right hemisphere (t[19]=3.74, p<.001), but not over the left hemisphere (t[19]=0.74, p>.05). Furthermore, to dissect the interaction of "hemisphere x pre- vs. post-training x response", a second set of ANOVAs of P2 mean amplitudes averaged across Asian and Caucasian faces and analyzed separately for pre- and post-training assessment yielded a significant interaction of "hemisphere x response" (F[1,19]=14.05, p<.001) in the pre-training assessment, with more positive-going amplitudes to CRs over the left hemisphere (t[19]=-3.23, p<.05), but no significant differences between hits and CRs over the right hemisphere (t[19]=0.58, p>.05). An analogous ANOVA for the post-training assessment showed no significant main effects or interactions for the factors "hemisphere" and "response" (all p>.05). Finally, analysis of left-hemispheric P2 mean amplitudes averaged across pre- and post-training assessment yielded significant main effects of "face ethnicity" (F[1,19]=9.12, p<.05) and "response" (F[1,19]=7.35, p<.05), speaking for more positive-going mean amplitudes in the P2 time range to both Caucasian and CRs over the left hemisphere. The same analysis for mean amplitudes over the right hemisphere yielded a significant main effect of "face ethnicity" (F[1,19]=16.90, p<.001) only, indicating more positive-going mean amplitudes to Caucasian faces.

N250: An ANOVA for N250 mean amplitudes (cf. Fig. 4) at P9 and P10 revealed a significant main effect of "face ethnicity" (F[1,19]=9.28, p<.05) which was qualified by a significant interaction of "hemisphere x pre- vs. post-training x face ethnicity" (F[1,19]=8.05, p<.05). Additionally, a significant interaction of "hemisphere x pre- vs. post-training x response" (F[1,19]=6.42, p<.05) was observed. Follow-up analyses of the former interaction with mean amplitudes averaged across hits and CR indicated significantly more negative N250 mean amplitudes to Asian faces (F[1,19]=7.99, p<.05) during pre-training assessment, whereas no such ethnicity-dependent amplitude differences were statistically significant

during post-training assessment (p>.05). Interestingly, however, there was a trend for an interaction of "hemisphere x face ethnicity" (F[1,19]=4.23, p=.053) during post-training assessment, with numerically more negative amplitudes to Asian as compared to Caucasian faces over the right hemisphere. Following-up the second interaction, analyses of N250 mean amplitudes averaged across face ethnicity during the pre-training session showed a significant interaction of "hemisphere x response" (F[1,19]=5.53, p<.05), speaking for significantly more negative-going amplitudes to hits as compared to CRs over the left hemisphere (t[19]=-2.92, p<.05), but not over the right hemisphere (t[19]=1.01, p>.05). A subsequent analysis for the post-training assessment yielded neither significant main effects of "hemisphere" or "response", nor a significant interaction of these factors (all p>.05).

- enter Table 4 about here -

Old/New-Effect: For the test phases, mean amplitudes in the time window of the Old/New-effect (cf. Table 4 and Fig. 5) were analyzed over F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 with the within-subject factors "face ethnicity", "pre- vs. post-training", "response", "anterior/posterior position" and "laterality". An ANOVA of the Old/New-Effect yielded significant main effects for "anterior/posterior position" (F[1.6,30.5]=47.95, p<.001), "response" (F[1,19]=15.27, p<.001), with more positive mean amplitudes to hits as compared to CRs, and significant interactions of "anterior/posterior position x laterality" (F[3.1,60.5]=7.28, p<.001), "anterior/posterior position x face ethnicity" (F[2,38]=14,97, p<.001), "laterality x pre- vs. post-training x face ethnicity" (F[2,38]=3.32, p<.05) as well as a trend for an interaction of "pre- vs. post-training x face ethnicity" (F[1,19]=4.22, p=.054). To account for the interaction of "laterality x pre- vs. post-training x face ethnicity", post-hoc analyses were calculated separately for left, midline and right recording sites and pre-/post-training assessment. Whereas significantly more positive mean amplitudes to Asian as

compared to Caucasian faces were recorded over midline (F[1,19]=10,64, p<.05) and right (F[1,19]=11,78, p<.05) recording sites before training, no ethnicity-dependent amplitude differences were observed following training (all F<1, p>.05).

- enter Figure 5 about here -

3. Discussion

By comparing the behavioral own-race bias before and after intensive individuation training with own- and other-race faces, the present study aimed at developing expertise with other-race faces in initially naïve participants. In addition to comparing behavioral measures of the own-race bias before and after training, ERPs were recorded and analyzed in regard to effects of both face ethnicity and training.

Behavioral results

A comparison of recognition performance before and after training revealed a lower own-race bias following individuation training. However, this reduced difference in recognition memory accuracy between own- and other-race faces was in fact largely due to decreased recognition to Caucasian faces after training, rather than to increased recognition performance to Asian faces. To explain these somewhat counterintuitive findings, several aspects might be worth considering.

First, a previous study on the recognition of *identical* stimuli in pre- and post-training assessment reported better recognition of other-race faces following individuation training with comparable intensity and length (Tanaka & Pierce, 2009). In contrast to this study, the current experiment examined effects of training on *different* stimuli in pre- and post-training assessment, therefore testing for a transfer of training effects on face recognition performance to completely novel stimuli. This difference between studies may account for the absence of improved recognition of other-race faces following training in the present experiment.

Specifically, even more extensive training may be necessary to create generalization of changes in face recognition performance to untrained other-race faces. In line with this argumentation, O'Toole and colleagues noted (O'Toole et al., 1991, p. 164) that short-term training studies involving practice with a limited spectrum of face ethnicities may be inadequate in regard to simulating real-world experience and accounting for an observer's lifetime experience with own-race faces.

Second, and according to the multi-dimensional face space hypothesis (Valentine & Endo, 1992), the observed changes in recognition memory performance to Caucasian faces and thus to the own-race bias may be interpreted as reflecting an initial stage of face space adaptation to other-race faces. More specifically, some of the critical dimensions used to discriminate individual faces in an observer's face space may have been modified to allow for more accurate representations of other-race faces. However, any initial change in face space, which has been optimally tuned to code own-race faces, should lead to less accurate representations for these stimuli. Thus, a reconfiguration of face space may initially result in inferior coding and recognition of own-race faces. At the same time, these initial adaptations of face space may not have been sufficient to cause substantially more accurate representations of other-race faces, and hence did not yield significantly increased recognition performance.

Analyses of response bias measures indicated more conservative responses to Asian faces following training. This finding may represent a shift in participants' strategy when discriminating Asian faces, which may reflect an increased understanding of discrepancies in own- and other-race face recognition as a result of training. According to socio-cognitive accounts of the own-race bias, it has been suggested that sensitizing participants for the own-race bias may suffice to abolish the effect (Hugenberg et al., 2007). In line with this, training may have induced participants to allocate more attention to other-race faces. However, participants did not exhibit better recognition memory performance despite this shift in

response bias, which is not in line with socio-cognitive accounts stressing the importance of situational factors on the own-race bias. Rather, these findings are most compatible with accounts stressing the importance of long-term expertise.

Electrophysiological results

Analysis of ERP correlates during learning phases yielded results with respect to effects of ethnicity on N170 and P2 that were similar to our previous study (Stahl et al., 2010). More specifically, N170 was delayed and enhanced to other-race faces as compared to own-race faces and mean amplitudes in the P2 time range were more positive to own- as compared to other-race faces. These findings are consistent with previous results on amplitude differences in the N170 (Herrmann et al., 2007; Walker et al., 2008; Stahl et al., 2008; Stahl et al., 2010) and P2 components (Stahl et al., 2010) as a function of face ethnicity or age (Wiese et al., 2008) in studies concerned with the recognition of individual faces of different categories (own-race vs. other-race, own-age vs. other-age). Taken together, the findings could be interpreted as reflecting ERP dissociations of in- and out-group faces in regard to specific face processing tasks that require participants to generate detailed structural representations of individual faces. Additionally, the observed N170 latency delay for Asian faces may be interpreted as an effect of specific category information in faces, which has been observed in studies concerned with the processing of ethnicity in faces (Stahl et al., 2008; Wiese et al., 2009; Stahl et al., 2010), but not when processing age-related information (Wiese et al., 2008). Importantly, training also affected N170 latency in that earlier N170 peaks were recorded in post-training assessment as compared to pre-training assessment, an effect that was independent of the ethnicity effects described above. Consistent with similar results (Tanaka & Pierce, 2009), these findings may be interpreted as reflecting more efficient structural encoding.

Similar to the learning phases, we also detected delayed and increased N170 amplitudes to other-race faces during test phases. In addition, P1 latency was slightly increased for Asian faces. Importantly, analyses of ERP recordings during test phases yielded significant interactions of ethnicity and training on several ERP components, whereas ERP findings yielded no such effects during learning. It thus appears that individuation training had no differential effect on *encoding* faces into memory, but on the processes during *retrieval* from memory. In a previous study (Stahl et al., 2010), an attractiveness rating task resulted in highly similar ERP correlates of own- and other-race face processing during learning phases despite no effect on the behavioral own-race bias. Thus, the absent effect of training on the recognition of other-race faces in the current study is presumably not due to differential encoding of own- and other-race faces.

Most importantly, training affected the lateralization of ethnicity-dependent amplitude differences in the N170 in test phases. Whereas more negative N170 amplitudes to Asian faces were observed over the left hemisphere before training, an ethnicity-dependent effect was visible over the right hemisphere following training. In line with previous findings (Scott & Nelson, 2006) of functional lateralization of the N170, this shift in lateralization of ethnicity-dependent differences in N170 amplitude may argue for training-induced changes in the processing of own- and other-race faces. Whereas the left-hemispheric N170 has been interpreted to be more sensitive to the processing of facial features, the right-hemispheric N170 has been attributed to configural face processing (Scott & Nelson, 2006). The current findings may therefore suggest a training-induced shift from differences in feature processing towards differential configural processing of Asian and Caucasian faces.

Similarly, ethnicity-effects in P2 amplitudes varied as a function of training. Whereas in the pre-training assessment more positive-going mean amplitudes were observed for Caucasian as compared to Asian faces over both hemispheres, an ethnicity-dependent amplitude difference was not detected over the left hemisphere in the post-training

assessment. This pattern of results appears strikingly similar to findings from an earlier study on the role of task demands (Stahl et al., 2010). Ethnicity-dependent differences in P2 amplitude over the left hemisphere were absent in a participant group that performed an attractiveness rating task during learning. In contrast, another group of participants performing an ethnicity categorization task exhibited bilateral P2 amplitude differences for own- and other-race faces. Taken together, it appears plausible that both task demands to differentiate between individual other-race faces and individuation training similarly result in the absence of *left-hemispheric* ethnicity-dependent P2 effects. Importantly, these modulations, which are likely strategic in nature, do not necessarily seem to be accompanied by changes in the behavioral own-race bias. In contrast, the absence of a *right-hemispheric* ethnicity effect in P2 amplitude was paralleled by a reduced behavioral own-race bias in a group of experts for other-race faces (Stahl et al., 2008; Stahl et al., 2010).

At the moment, it is not possible to determine the exact processes underlying these effects. However, it is commonly assumed that expertise with a certain group of faces (own-race faces) is related to enhanced processing of holistic and configural information (Michel et al., 2006; Rhodes et al., 2006). Moreover, the processing of second-order configural information has been suggested to be critical for the processing of identity-relevant information in faces (Maurer et al., 2002) and hence for the recognition of individual faces (Diamond & Carey, 1986). More recently it has been shown that the experience-driven fine-tuning of configural processing mechanisms to own-race faces is linked to a decrease in the behavioral own-race bias (Hancock & Rhodes, 2008; Rhodes et al., 2009a). Thus, the finding of a decreased own-race bias in the absence of a right-hemispheric P2-effect in experts for other-race faces may reflect similar second-order configural processing for faces of both ethnic groups.

In addition to training effects on N170 and P2, analysis of ERP waveforms in the time window of the old/new-effect in test phases revealed significantly more positive mean

amplitudes to Asian as compared to Caucasian faces over midline and right electrode sites in the pre-training assessment, but no significant difference following training. Similar findings were detected in the learning phases of our previous experiment (Stahl et al., 2010), in which a more positive LPC for other-race faces was observed in the categorization task, but not in the attractiveness rating task. As a conclusion from both studies, these findings may suggest that participants' attention was shifted towards the processing of other-race faces, either as a result of task demands during learning or individuation training, which, however, did not yield a reduced own-race bias. These results are hard to explain through purely socio-cognitive theories of the own-race bias, which assume that strategic changes in the processing of own- and other-race faces affect the own-race bias even in the absence of other-race face expertise (Levin, 2000). In contrast, non-experts in our previous and the present study were presumably not able to benefit from a change in strategic processing.

In sum, the present study clearly demonstrated that training participants to individuate own- and other-race faces affects both the behavioral own-race bias and its electrophysiological correlates. Although the behavioral own-race bias was significantly reduced in magnitude following several learning sessions, this was *not* due to enhanced recognition of other-race faces, but to *decreased* recognition of own-race faces after training. We assume that participants in the current study learned to shift their attention to facial characteristics useful for distinguishing between other-race faces, which may have been at the cost of encoding relevant information for the discrimination of own-race faces. Therefore, the behavioral results from the current study are not in line with a purely socio-cognitive approach to the own-race bias, since participants were unable to benefit from individuation training even though they were aware of the challenges in own- and other-race face recognition.

In addition to behavioral findings of training effects, ERPs to own- and other-race faces showed clear effects of both ethnicity and training. N170 was generally delayed and increased to other-race faces, and earlier N170 peaks as a result of individuation training as well as a training-induced hemispheric shift in ethnicity effects regarding N170 amplitude were observed. Importantly, analyses of the P2 yielded evidence for an interaction of face ethnicity and training effects. Training modulated bilaterally enhanced P2 amplitudes to own-race faces in test phases, resulting in an abolished P2 amplitude difference over the left hemisphere after training. We therefore assume that training induced more similar processing of own- and other-race faces, but, given the behavioral results, did not enhance the mechanisms specifically relevant for the correct recognition of other-race faces. These mechanisms are presumably reflected in right-hemispheric P2 amplitude differences for own- and other-race faces. In conclusion, the present findings are thus in line with accounts of the own-race bias, which emphasize the role of long-term expertise to underlie this phenomenon.

4. Experimental procedure

Participants: Twenty-one Caucasian undergraduate students from the University of Jena and the University of Applied Sciences in Jena participated in the study. They were compensated with either course credit or a payment of € 5/h. All participants were right-handed, according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971), and reported normal or corrected-to-normal vision. Due to poor quality of the EEG-recordings, one participant was excluded from statistical analyses. Thus, 20 participants (Mean Age = 23.9 years, *SD* = 3.61; 13 female) contributed data. All participants gave informed written consent, and the study was conducted in accordance with the Declaration of Helsinki.

Stimuli: Stimuli for the pre- and post-training measurements consisted each of 96 unfamiliar Caucasian (own-race) faces and 96 unfamiliar Asian (other-race) faces (50 %

female, respectively). Stimuli displayed front-view faces with neutral expression, the majority of which were taken from the CAL/PAL Database (Minear & Park, 2004), the FRI CVL Face Database (Solina et al., 2003) and the NimStim Face Database (Tottenham et al., 2009). Since two different stimulus sets were compiled for pre- and post-training assessment from a general stimulus pool, a total of 192 Caucasian and 192 Asian faces were displayed in the two recognition memory sessions, with stimuli from the different databases symmetrically distributed into the two parallel stimulus sets for pre- and post-training.

For the training sessions, stimuli were extracted from the FERET database (Phillips et al., 1998; Phillips et al., 2000), consisting of 240 facial photographs of 80 individuals (50% Asian, 50% female). For each individual, photographs depicted faces with neutral expression from three different viewing angles – frontal view, left and right half profile view. Importantly, none of the stimuli employed in the learning sessions were used in the pre- and post-training measurements.

Using Adobe Photoshop^{TM}, all stimuli were edited in order to substitute the existing background with a uniform black background. Subsequently, stimuli were converted to gray-scale and cropped to a size of 170 x 216 pixels (6.0 x 7.6 cm), resulting in a visual angle of 3.8° x 4.8° at a viewing distance of 90 cm.

Procedure:

Pre- and posttraining tests: Participants were seated in front of a computer screen in a dimly lit, electrically shielded and noise-attenuated chamber (400-A-CT-Special, Industrial Acoustics, Niederkrüchten, Germany) with their heads in a chin rest so as to provide for a constant distance to the monitor of 90 cm.

For all participants in both pre- and posttest assessment, the experiment consisted of a practice block (8 learning and 16 test trials) and 5 *experimental blocks*. Each block was divided into a *learning phase* and a *test phase*. Individual trials always adhered to the same pattern: first, a fixation cross was displayed for a duration of 500 ms, followed by stimulus

presentation for either 5000 ms (learning phase) or 2000 ms (test phase). Each trial ended with a blank screen, which was presented for 500 ms. Participants had to respond via button presses within 5000 ms (learning phase) or 2000 ms (test phase) after stimulus onset, respectively. During a learning phase, 20 faces (10 Asian and 10 Caucasian; 50% female, respectively) were presented to the participants (blocks 4 and 5 included only a total of 18 learning faces), who were instructed to decide as fast and accurately as possible whether a given face was Asian or Caucasian. In addition, participants were instructed to memorize each individual face. Learning and test phases were separated by a 30 s break. During the ensuing test phase, 40 faces (all 20 faces from the directly preceding learning phase and 20 new faces) were presented in randomized order (for blocks 4 and 5, 36 faces were presented in total). Participants had to decide as fast and accurately as possible whether a given face had been presented in the directly preceding learning phase ("learned") or not ("new"). Between experimental blocks, participants were allowed a self-timed period of rest. Key assignment was counterbalanced across participants. All responses were scored as correct if the correct response key was pressed within a time window of 5000 ms or 2000 ms after stimulus onset during learning and test phases, respectively. All mean reaction times reported are based on correct responses only.

Training sessions: Following the pre-training test, participants attended five individual learning sessions that were generally spread over a maximum period of 14 days, and were typically held over consecutive days.

During each training session, participants learned to individuate 8 novel Asian and 8 novel Caucasian faces (50% female each). Learning sessions always adhered to the same pattern and consisted of one block for each gender, resulting in a total of two blocks per learning session. Sequence of the gender blocks was randomized across participants. Each gender block was divided into four sub-blocks, which were presented in successive order, with the first sub-block containing one face from each ethnicity, the number of which

increased to a total of four faces from each ethnicity in the fourth sub-block. During each sub-block, participants were presented with a screen containing three different photographs (frontal view, left and right half profile) of the same face, accompanied by a name, for the duration of 5000 ms. Participants were required to memorize each individual face and its respective name for later recognition. Following the learning phase, participants entered a test phase, during which they were shown randomly selected pictures of the previously encountered photographs for each given individual for 2000 ms and were required to denote the individual's correct name by pressing the corresponding button for one out of four displayed names. Responses were recorded via button press. Following each test phase, accuracy was calculated and feedback was given to participants as to whether they had named all faces correctly. In the case that a participant committed mistakes during the recognition test, he/she was required to repeat the learning and test cycles until accuracy amounted to 100%. Once participants had completed the recognition test error-free, they proceeded to the next sub-block, in which they repeated the previously learned faces in addition to learning two new faces (one Asian, one Caucasian). Accordingly, two new faces were introduced with each additional sub-block, until participants were able to correctly recognize and name four Asian and four Caucasian individuals at the end of the fourth sub-block. After successful completion of the second gender block, each learning session concluded with participants having learned eight faces of each ethnic group.

For each learning session, different face stimulus and name sets were used and the sequence of learning sessions was randomized across participants. All depicted individuals were assigned English first names to control for name complexity. Furthermore, assignment of names to Asian and Caucasian faces was counterbalanced across participants to avoid stimulus effects. Name stimuli were chosen from a list of most popular given names in 2007 (list obtained from the U.S. Social Security Administration via http://www.ssa.gov/cgi-bin/popularnames.cgi, accessed on 03/06/2009). From that list, a selection of the top 40

female and male names was made, excluding duplicates and related names (e.g. Jack vs. Jackson, Alexis vs. Alexa) as well as names without a clear gender denomination (e.g. Taylor).

Behavioural data:

Pre- and posttraining tests: Reaction times (RT) and responses were recorded and analyzed during learning and test phases. For learning phases, responses and mean RTs were computed separately for Asian and Caucasian faces. For the test phases, responses were sorted into four different categories for both Asian and Caucasian faces: hits (correctly identified learned faces), misses (learned faces incorrectly classified as new), false alarms (FA, new faces incorrectly classified as learned) and correct rejections (CR, correctly classified new faces). Measures of sensitivity (d') and response criterion (C) were calculated for both Asian and Caucasian faces in each group of participants according to signal-detection theory (cf. Green & Swets, 1966):

$$d' = z(hits) - z(FA) \quad and \quad C = -\tfrac{1}{2}\,[z(hits) + z(FA)]$$

Furthermore, measures for the Own-Race Bias (ORB) were calculated according to MacMillan and Creelman (Macmillan & Creelman, 1991) using the following formula:

$$ORB = (d'_{OR} - d'_{SR})/(d'_{OR} + d'_{SR}),$$

with d'_{OR} indicating sensitivity for other-race faces and d'_{SR} indicating sensitivity for same-race faces (own-race faces).

Statistical analysis of accuracy data from the learning phase was omitted due to ceiling effects. Reaction times from learning and test phases, as well as responses in the test phases were analyzed with separate repeated-measures ANOVAs with the within-subject factors "face ethnicity" (Asian, Caucasian) and "response type" (hits, CR; only for test phases) as well as the factor "pre-/post training". Additionally, z-transformed measures such as d' and response bias (C) were evaluated using non-parametric tests (Wilcoxon-Test) for comparison of differences in regard to assessment date and face ethnicity.

Electrophysiological recording and analysis: EEG was recorded using a 32-channel BioSemi Active II system (BioSemi, Amsterdam, Netherlands). Active sintered Ag/AgCl-electrodes were mounted in an elastic cap with recording sites at Fz, Cz, Pz, Iz, FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, F9, F10, FT9, FT10, TP9, TP10, P9, P10, PO9, PO10, I1 and I2. EEG was recorded continuously with a 512-Hz sampling rate from DC to 120 Hz. Please note that BioSemi systems work with a "zero-Ref" setup with ground and reference electrodes replaced by a so-called CMS/DRL circuit (cf. to http://www.biosemi.com/faq/cms&drl.htm for further information).

Contributions of blink artefacts were corrected using the algorithm implemented in BESA 5.1 (Berg & Scherg, 1994). Subsequently, EEG was segmented from -200 until 1200 ms relative to stimulus onset, with the first 200 ms as baseline. Only trials with correct responses in the learning and test phases (hit, CR) entered the analysis. Trials contaminated by non-ocular artefacts and saccades were rejected from further analysis. Artefact rejection was carried out using the BESA 5.1 tool, with an amplitude threshold of 100 μV, as well as a gradient criterion of 75 μV. The remaining trials were recalculated to average reference, averaged according to experimental condition and digitally low-pass filtered at 20 Hz (12 db/oct, zero phase shift). Therefore, three different waveforms (learning phase, hits, CR) were calculated for each ethnicity and assessment date.

For statistical analyses, ERP components were analyzed at the electrodes of their respective maximal amplitudes. Therefore, P1 latency was analyzed at O1 and O2 between 80 and 140 ms, whereas N170 latency was determined at P9 and P10 between 120 and 200 ms after stimulus onset. Individual peak amplitudes relative to a 200 ms baseline were determined at O1 and O2 for the P1 component and at P9 and P10 for the N170 component. For later time segments, mean amplitudes relative to a 200 ms baseline were computed at P9 and P10 between 220 and 260 ms for the P2 component and between 260 and 340 ms for the N250 component, whereas mean amplitudes for the late positive component (LPC) and the

Old/New-Effect were calculated between 400 and 700 ms at frontal, central and parietal electrodes (F3, Fz, F4, C3, Cz, C4, P3, Pz and P4). Statistical analysis of ERPs for P1, N170, P2 and N250 from the learning phases was performed by using mixed model ANOVAs with the within-subject factors “hemisphere”, “pre-/post-training” and “face ethnicity”. Analyses of ERPs for the test phases included an additional within-subject factor “response” (hits vs. CR). Finally, analyses for the LPC and Old/New-Effect additionally included two within-subject factors “anterior/posterior position” (frontal, central and posterior) and “laterality” (left, midline and right; replacing the factor “hemisphere”) to account for the various electrode positions that were entered into the analyses. For all analyses, degrees of freedom were corrected according to Huynh-Feldt where appropriate and significant interactions were further analyzed by follow-up comparisons.

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- Illustrations and figure captions:

Figure 1: Schematic overview over the sequence of experimental sessions, with pre-training own-race bias assessment, individuation training sessions and post-training own-race bias assessment

Figure 2: Grand Mean waveforms for P1, N170 and P2 ERP components for Asian and Caucasian faces during learning phases in pre-training and post-training assessment. ERPs are plotted from -50 – 400 ms for P9/P10 and O1/O2. Note the P2 effects of face ethnicity and training.

Figure 3: Grand Mean waveforms LPC and old/new effect for Asian and Caucasian faces during learning phases in pre-training and post-training assessment. ERPs are plotted from -100 – 800 ms.

Figure 4: Grand Mean waveforms for P1, N170 and P2 ERP components for Asian and Caucasian faces during test phases in pre-training and post-training assessment. ERPs are plotted from -50 – 400 ms for P9/P10 and O1/O2. Note the P2 effects of face ethnicity and training.

Figure 5: Grand Mean waveforms LPC and old/new effect for Asian and Caucasian faces during test phases in pre-training and post-training assessment. ERPs are plotted from -100 – 800 ms.

- Tables:

		Pre-training		*Post-training*	
		M	SE_M	*M*	SE_M
Learning phases					
RTs (ms)	Caucasian	837.81	53.35	774.88	45.63
	Asian	804.01	63.68	732.71	44.05
Test phases					
RTs (ms)	Caucasian (hits)	900.80	37.25	858.09	29.63
	Caucasian (CR)	953.80	42.50	930.70	36.73
	Asian (hits)	939.72	37.94	900.40	29.71
	Asian (CR)	1011.48	44.39	946.96	35.77
Hit-rates					
	Caucasian	80.93	2.80	80.36	2.86
	Asian	74.27	2.32	69.21	3.12
CR-rates					
	Caucasian	91.56	1.91	87.52	2.01
	Asian	80.52	2.64	85.93	1.75
C					
	Caucasian	0.27	0.08	0.15	0.06
	Asian	0.12	0.06	0.30	0.07
d'					
	Caucasian	2.50	0.16	2.17	0.14
	Asian	1.63	0.13	1.69	0.10
Own-Race Bias					
		-0.21	0.02	-0.12	0.02

Table 1: Mean values and standard errors for responses, response criterion (C), accuracies (d'), Own-Race Bias and reaction times for learning and test phases in pre- and post-training assessment

		Pre-training				*Post-training*			
		M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M
P1 latency (ms)		*O1*		*O2*		*O1*		*O2*	
	Caucasian	110.1	2.35	108.1	2.50	109.6	2.75	107.7	2.53
	Asian	110.2	2.37	108.5	2.71	110.8	2.75	108.5	2.29
P1 amplitude (μV)		*O1*		*O2*		*O1*		*O2*	
	Caucasian	7.361	1.24	7.361	1.07	7.730	1.16	6.775	1.05
	Asian	7.777	1.20	7.374	1.09	7.704	1.16	6.751	1.08
N170 latency (ms)		*P9*		*P10*		*P9*		*P10*	
	Caucasian	173.2	3.56	166.4	3.51	168.1	3.16	158.9	2.70
	Asian	175.0	3.42	169.7	3.88	171.9	3.52	165.2	3.50
N170 amplitude (μV)		*P9*		*P10*		*P9*		*P10*	
	Caucasian	-3.425	0.61	-6.662	0.56	-3.524	0.75	-6.761	0.66
	Asian	-4.382	0.54	-6.819	0.57	-4.684	0.73	-6.556	0.74
P2 mean amplitudes (μV; 220-260 ms)		*P9*		*P10*		*P9*		*P10*	
	Caucasian	-0.133	0.57	-1.117	0.52	0.185	0.57	-0.325	0.33
	Asian	-1.950	0.56	-1.455	0.49	-1.685	0.53	-1.103	0.40
N250 mean ampli-tudes (μV; 260-340 ms)		*P9*		*P10*		*P9*		*P10*	
	Caucasian	-0.472	0.54	-1.043	0.57	-0.045	0.50	-1.126	0.39
	Asian	-2.227	0.62	-1.485	0.61	-2.253	0.61	-1.745	0.58

Table 2: ERP measures for P1, N170, P2 and N250 during the learning phases in pre- and post-training sessions

	Pre-training				*Post-training*			
	M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M
P1 latency (ms)	*O1*		*O2*		*O1*		*O2*	
Caucasian (hits)	108.9	2.63	107.0	2.46	108.3	2.69	104.8	2.51
Caucasian (CR)	110.0	2.23	109.3	2.40	108.1	2.50	105.2	2.87
Asian (hits)	110.5	2.30	109.5	2.59	109.4	2.89	107.3	2.48
Asian (CR)	111.3	2.31	110.1	2.56	109.7	2.82	108.7	2.54
P1 amplitude (μV)	*O1*		*O2*		*O1*		*O2*	
Caucasian (hits)	8.213	1.21	7.509	1.07	7.438	1.23	6.684	1.04
Caucasian (CR)	7.781	1.19	7.177	1.03	7.947	1.22	6.877	1.05
Asian (hits)	7.850	1.26	7.384	1.08	8.023	1.33	7.037	0.99
Asian (CR)	8.208	1.22	7.600	1.10	7.661	1.24	6.809	1.03
N170 latency (ms)	*P9*		*P10*		*P9*		*P10*	
Caucasian (hits)	171.7	4.12	164.1	3.86	160.0	2.19	155.8	2.67
Caucasian (CR)	171.1	4.36	164.7	3.96	162.5	3.13	157.4	2.66
Asian (hits)	174.2	4.23	167.0	3.98	165.3	3.16	158.8	2.71
Asian (CR)	171.4	3.45	167.5	4.03	165.7	2.94	162.9	2.60
N170 amplitude (μV)	*P9*		*P10*		*P9*		*P10*	
Caucasian (hits)	-3.437	0.56	-5.931	0.49	-3.943	0.74	-6.322	0.63
Caucasian (CR)	-2.899	0.61	-6.337	0.52	-3.617	0.66	-6.169	0.58
Asian (hits)	-3.953	0.62	-6.669	0.53	-3.413	0.89	-7.575	0.71
Asian (CR)	-3.968	0.49	-6.761	0.64	-3.627	0.75	-6.531	0.61
P2 mean amplitudes (μV; 220-260 ms)	*P9*		*P10*		*P9*		*P10*	
Caucasian (hits)	-0.646	0.54	-0.328	0.37	-0.032	0.50	0.185	0.42
Caucasian (CR)	0.074	0.55	-0.782	0.50	0.225	0.39	0.410	0.40
Asian (hits)	-1.519	0.36	-1.333	0.31	0.061	0.51	-1.051	0.50
Asian (CR)	-1.059	0.45	-1.217	0.48	-0.192	0.45	-0.576	0.47
N250 mean amplitudes (μV; 260-340 ms)	*P9*		*P10*		*P9*		*P10*	
Caucasian (hits)	-1.074	0.45	-1.049	0.42	-0.703	0.48	-1.349	0.58
Caucasian (CR)	-0.485	0.47	-1.444	0.43	-0.374	0.43	-1.097	0.47
Asian (hits)	-2.181	0.39	-1.743	0.54	-0.308	0.53	-2.122	0.64
Asian (CR)	-1.677	0.45	-1.962	0.53	-0.855	0.51	-1.614	0.52

Table 3: ERP measures for P1, N170, P2 and N250 during the test phases in pre- and post-training assessment

		Pre-training				*Post-training*			
		M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M
LPC (μV, 400-700 ms)		*Caucasian*		*Asian*		*Caucasian*		*Asian*	
F3		-0.751	0.64	-0.679	0.59	-0.056	0.79	-0.359	0.71
Fz		-2.505	0.65	-2.145	0.77	-1.993	0.67	-1.539	0.79
F4		-0.186	0.55	0.295	0.58	0.204	0.51	-0.305	0.82
C3		-0.789	0.66	-0.408	0.57	0.583	0.54	0.608	0.65
Cz		-2.099	0.91	-0.917	0.92	-1.826	0.77	-0.746	0.99
C4		0.294	0.71	1.269	0.66	0.436	0.70	2.313	0.72
P3		4.813	0.65	5.207	0.44	4.867	0.66	5.263	0.65
Pz		4.952	0.68	5.958	0.80	5.057	0.75	6.430	0.86
P4		4.600	0.60	5.565	0.59	4.644	0.60	5.918	0.85
Old/New-Effect (μV, 400-700 ms)		*Caucasian*		*Asian*		*Caucasian*		*Asian*	
F3	old	0.313	0.76	-0.349	0.67	0.041	0.57	-0.217	0.69
	new	-0.454	0.61	-0.724	0.81	-0.240	0.68	-0.719	0.70
Fz	old	-0.681	0.69	-0.485	0.69	-0.485	0.55	-1.053	0.63
	new	-1.664	0.68	-2.282	0.78	-1.432	0.69	-2.140	0.81
F4	old	0.449	0.42	-0.007	0.61	0.627	0.47	0.191	0.46
	new	-0.805	0.58	-0.882	0.76	0.184	0.63	-1.250	0.76
C3	old	0.903	0.57	1.081	0.62	1.185	0.50	1.206	0.65
	new	0.302	0.54	0.236	0.55	0.798	0.38	0.663	0.46
Cz	old	0.406	0.96	1.223	0.78	0.412	0.74	0.400	0.93
	new	-0.601	0.89	0.104	0.91	-0.396	0.74	-0.708	0.88
C4	old	1.374	0.78	2.516	0.58	1.866	0.59	1.527	0.84
	new	0.919	0.67	2.010	0.73	1.006	0.60	1.400	0.77
P3	old	4.033	0.50	4.802	0.66	5.458	0.67	5.191	0.94
	new	3.918	0.54	4.859	0.66	4.142	0.60	4.810	0.77
Pz	old	4.889	0.91	6.803	0.82	6.215	0.95	6.529	1.07
	new	4.895	0.84	6.246	0.82	5.682	0.80	5.764	0.87
P4	old	4.798	0.72	6.228	0.78	5.335	0.83	5.469	0.86
	new	4.346	0.69	5.143	0.71	4.917	0.77	5.150	0.76

Table 4: mean amplitudes (400-700 ms) for LPC and Old/New-Effect for pre- and post-training assessments in learning and test phases, respectively

Figure1

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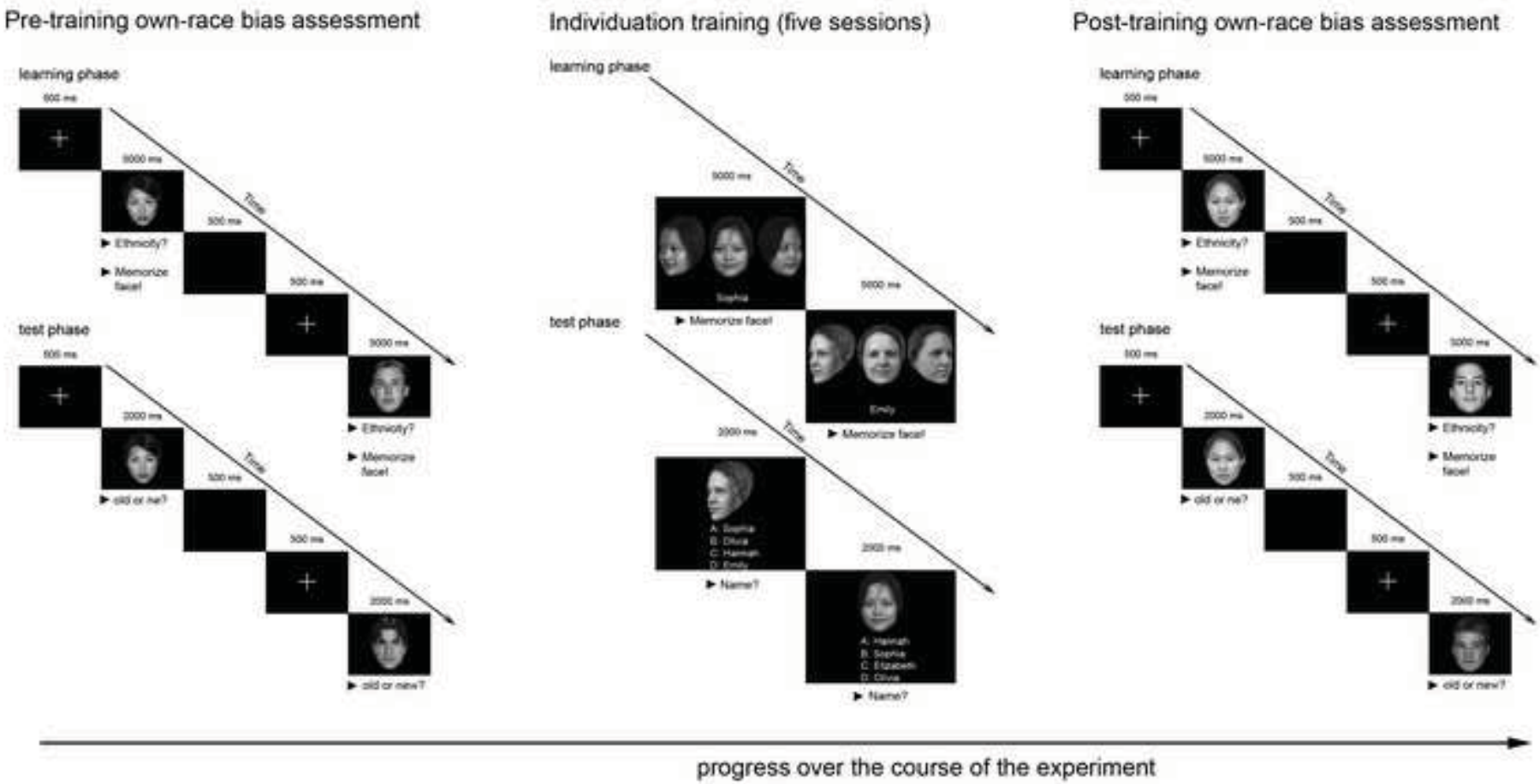

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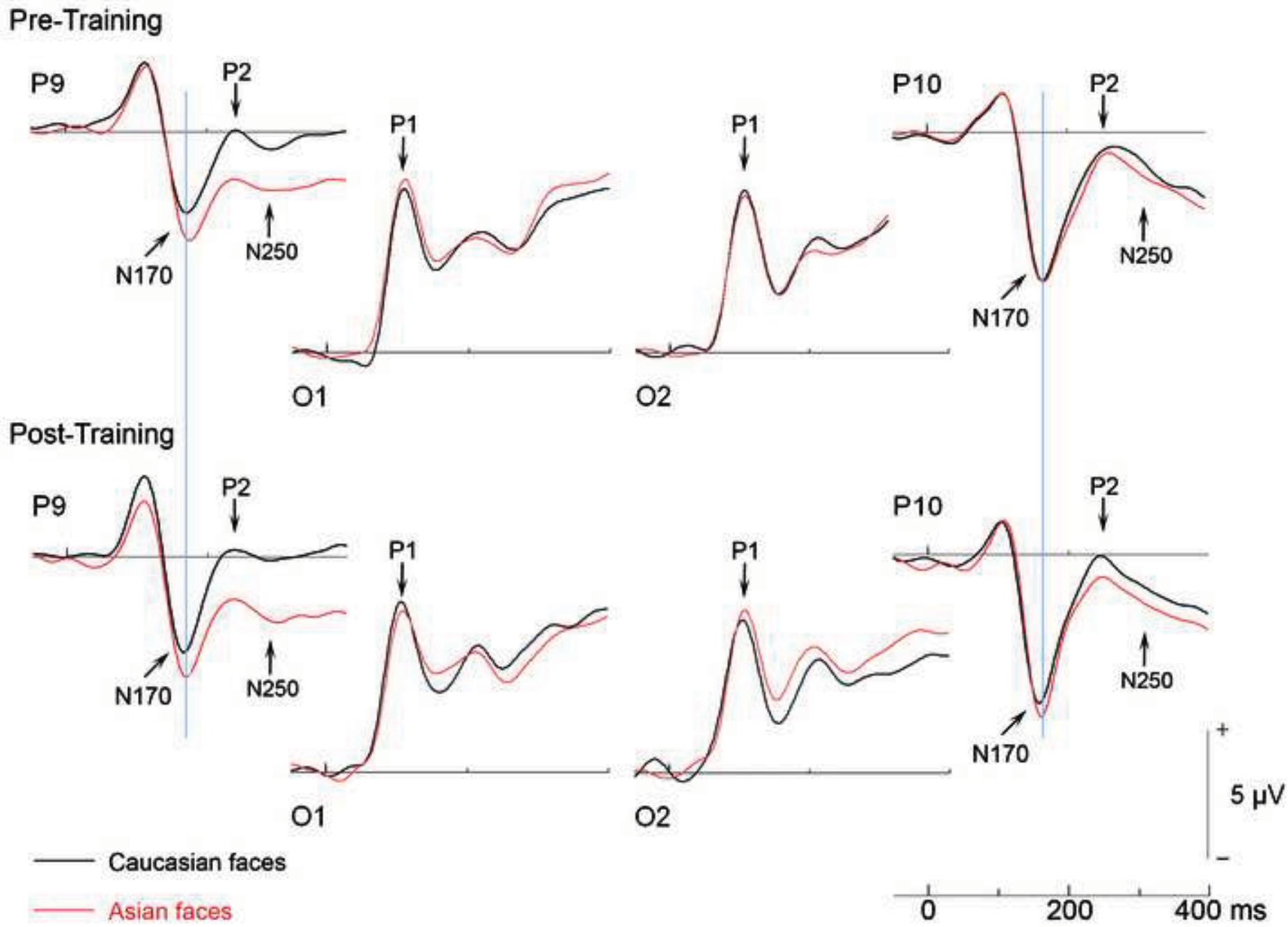

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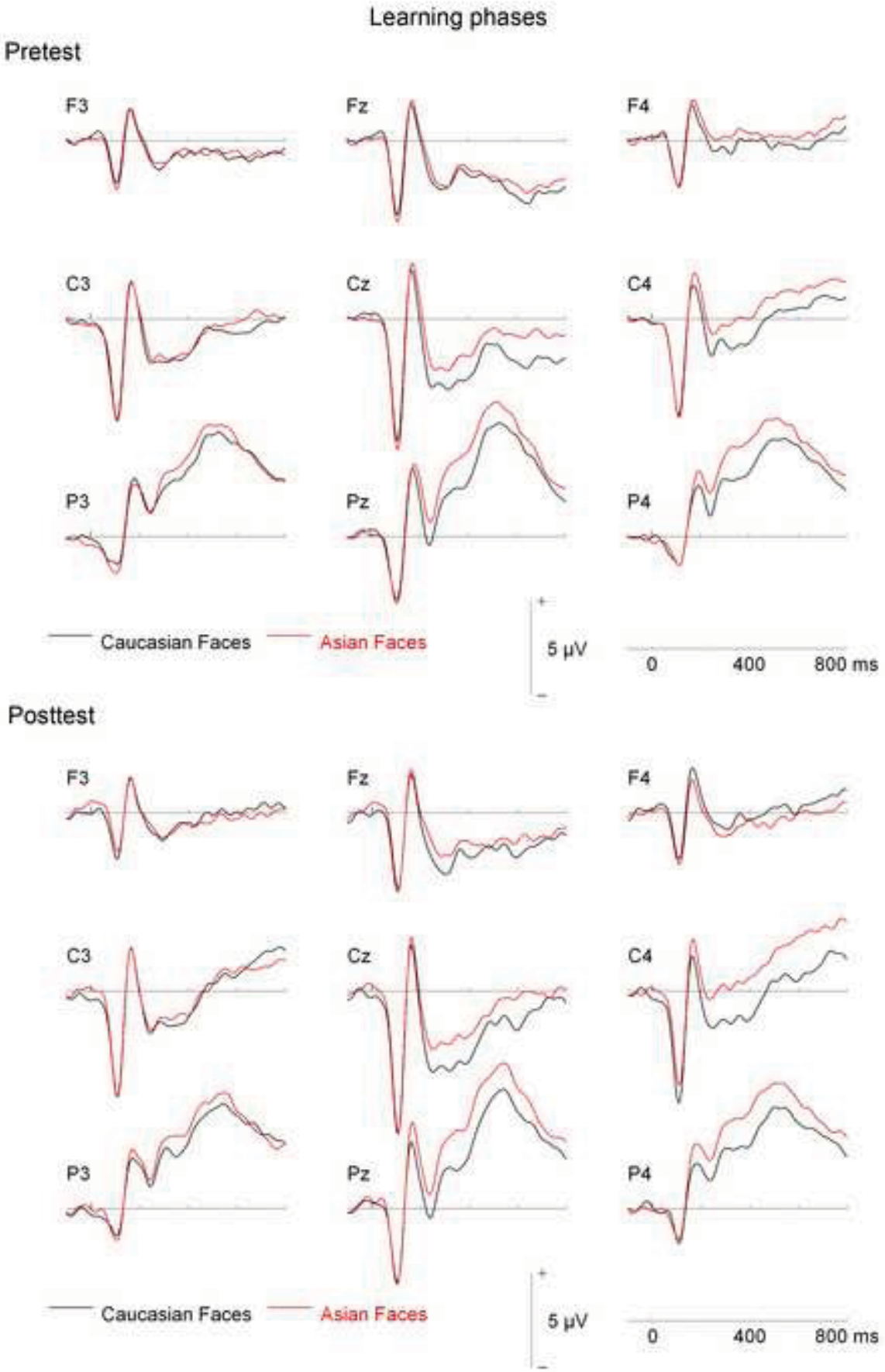

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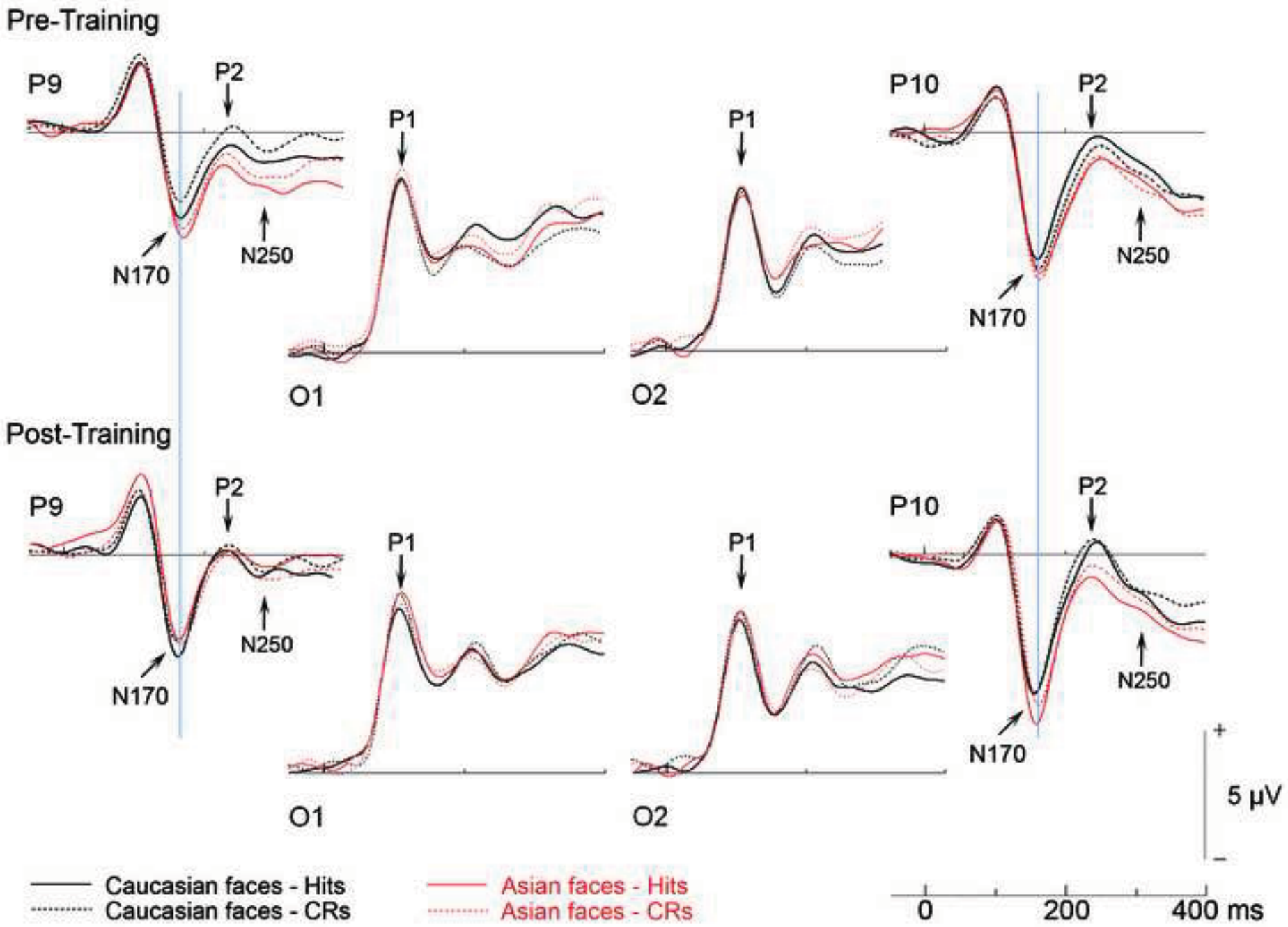

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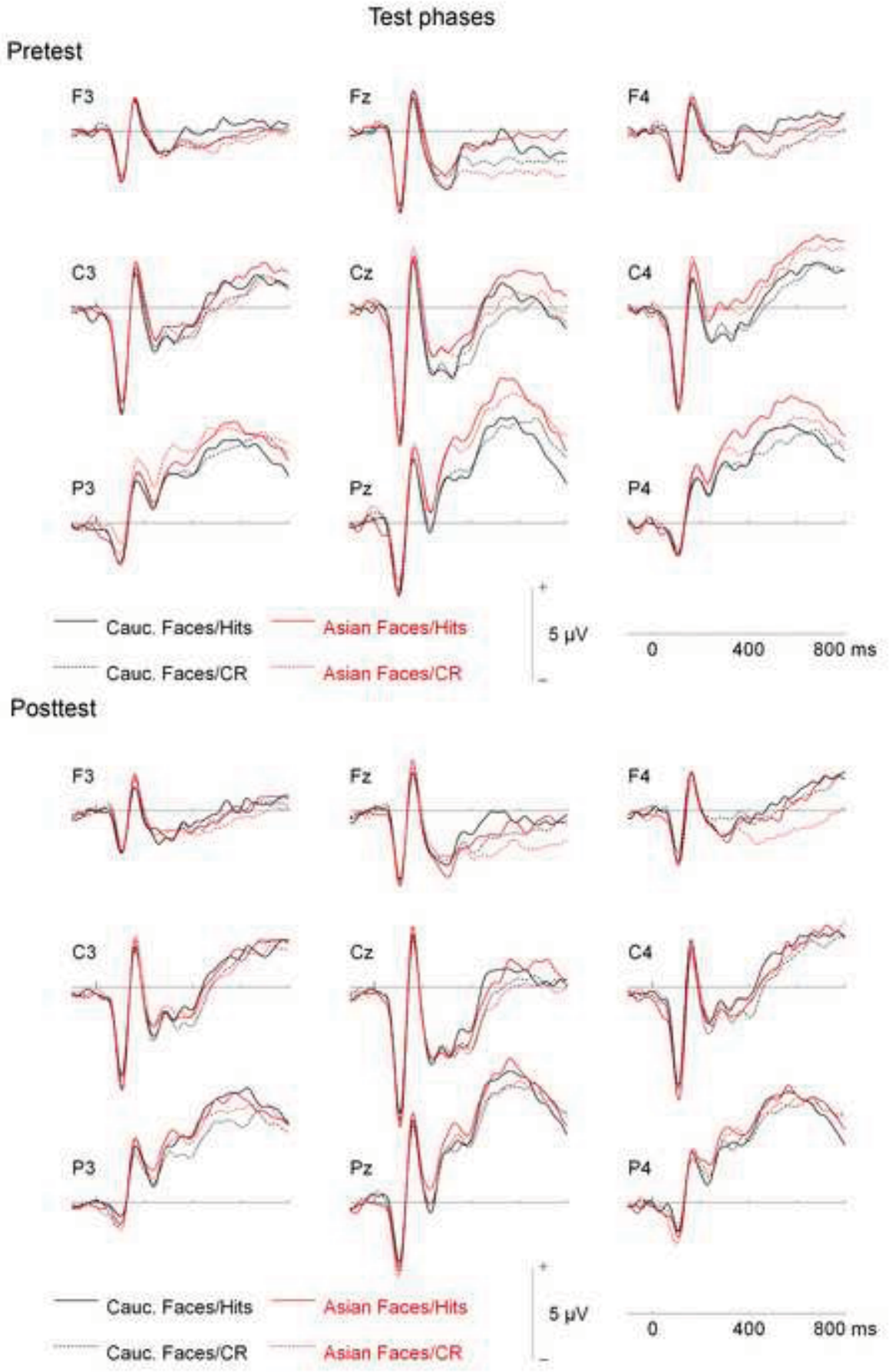

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Configural processing of other-race faces is delayed but not decreased

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ABSTRACT

The processing of other-race faces has been suggested to differ from own-race face processing with regard to the extent to which configural and/or holistic information is taken into account. We aimed at investigating the underlying mechanisms more precisely by applying event-related potentials (ERP). We presented upright and inverted own-race, other-race, and other-species faces (apes), as well as non-facial control stimuli (houses), and analysed the effects of stimulus type and inversion on the N170. Peak latencies for same-race, other-race, other-species, and non-face stimuli gradually increased, and inversion of all types of face stimuli led to an additional delay. Importantly, the two factors did not interact for face stimuli. Inversion increased N170 amplitudes for own- and other-race faces only. We conclude that early perceptual mechanisms of face processing are not qualitatively different for own- and other-race faces. Instead, the same underlying processes appear to work less efficiently for other-race faces.

1. Introduction

Although humans are often described as being experts in face processing, this proficiency does not seem to include all kinds of faces to the same extent. For instance, as early as at the age of 9 months infants discriminate between individual human faces but not monkey faces (Pascalis et al., 2002). Moreover, even within their species people remember faces of their own ethnic group more accurately than other-race faces—a well-described phenomenon that is known as the own-race bias (for a review, see Meissner and Brigham, 2001). As detailed below, previous research has reported differences not only with regard to recognition but also in perceptual processing of same- and other-race faces (see also Valentine and Endo, 1992).

Early perceptual face processing (or structural encoding, cf. Bruce and Young, 1986) has been suggested to involve several stages. Diamond and Carey (1986) described two different mechanisms that were subsumed as so-called configural processes: first, the detection of features arranged in a face-like configuration (two eyes above a nose, which is in turn above a mouth; first-order configural information) leads to the identification of a given stimulus as being a face. Second, to identify an individual face it is necessary to extract so-called second-order configural information, which refers to distances between the individual features of a face. In addition, it has been demonstrated that the components or features of a face cannot be treated independently but are merged into a holistic representation or gestalt (Tanaka and Farah, 1993). These three mechanisms (first-order configural processing, holistic processing, second-order configural processing) are typically distinguished as different aspects of configural face processing (Maurer et al., 2002). Importantly, the configural processing of faces is known to be severely disrupted by picture-plane inversion of the stimuli, i.e., by rotating them by 180°. This manipulation has been observed to affect the processing of faces to a larger extent than other non-facial stimuli (Yin, 1969; for reviews, see Valentine, 1988; Rossion, 2008).

Several authors assumed that the own-race bias originates from a more extensive configural and/or holistic processing of same-race compared to other-race faces (for a review on the different theoretical accounts on the own-race bias, see Meissner and Brigham, 2001). Accordingly, it has been suggested, that face inversion should affect the recognition of own-race faces more dramatically than the recognition of other-race faces. The empirical evidence, however, is mixed with some authors observing larger inversion effects for own-race compared to other-race faces (Rhodes et al., 1989; see also Hancock and Rhodes, 2008) and others reporting results incongruent with the above prediction (e.g., Valentine and Bruce, 1986).

More recently, however, several studies reported advantages for the processing of own-race compared to other-race faces in perceptual or matching tasks which were interpreted to be based on enhanced configural/holistic processing. First, the Thatcher

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illusion, describing the finding that faces with rotated eyes and mouth features appear bizarre when presented upright, but not when inverted, is usually interpreted as reflecting a deficit in configural processing. Murray et al. (2003) found that other-race Thatcherized faces appear less bizarre than own-race Thatcherized faces when presented in upright orientation. Second, configural (e.g., manipulations of the eye distance) and also component changes (e.g., manipulations of lip colour) have been observed to be more easily detected in own-race compared to other-race faces (Rhodes et al., 2006). Finally, more extensive holistic processing has been observed for same-race compared to other-race faces, both in the parts/whole task (Tanaka et al., 2004) and the face composite task (Michel et al., 2006a,b), which are considered to be hallmark paradigms for investigating holistic face processing.

It is important to note, however, that behavioural studies can only measure the outcome of perceptual analysis and can therefore not provide any direct information about the locus of effect or the temporal dynamics of the processing steps involved. By contrast, event-related potentials (ERPs), which consist of transient voltage changes in the electroencephalogram time-locked to a certain event, offer fine-grained chronometric measures of the neural operations during stimulus processing. Accordingly, ERPs have been successfully applied to study face perception and recognition processes.

The most extensively studied ERP component associated with face processing is the N170 (Bentin et al., 1996), a negative deflection over occipitotemporal areas, peaking approximately 170 ms after stimulus onset. Although the N170 has initially been found to be larger in amplitude over the right hemisphere for face stimuli, this finding was not reported to be significant in several of the subsequent studies (see e.g., Bentin and Deouell, 2000; Eimer, 2000; Itier and Taylor, 2002; Rossion et al., 1999, 2000). The N170 has been interpreted to reflect early processes of structural encoding prior to the identification of an individual face (Bentin and Deouell, 2000) or the detection of a face-like pattern (Schweinberger and Burton, 2003; Schweinberger et al., 2004). Also, this component has been argued not to be specific to the presentation of human faces (Rossion et al., 2000; Schweinberger et al., 2004), and has been demonstrated to depend on expertise with a given stimulus class (Tanaka and Curran, 2001). Following the presentation of inverted human faces, N170 is usually delayed and increased (e.g., Rossion et al., 1999, 2000; Itier and Taylor, 2002, 2004; Eimer, 2000; Latinus and Taylor, 2006; Itier et al., 2006; de Haan et al., 2002), which has been interpreted to reflect its sensitivity to configural processing. More recently, it has been suggested, that both first-order configural processing and holistic processes are reflected in the N170 (Latinus and Taylor, 2006). Accordingly, if, as suggested by the behavioural studies cited above, other-race faces are processed less configurally and/or holistically at the perceptual level, one might expect N170 to be delayed for these stimuli in comparison to own-race faces.

Consistent with this prediction we observed significantly delayed N170 latencies in Caucasian participants for other-race Asian compared to same-race faces in a previous study (Stahl et al., 2008). In this study, however, all stimuli were presented upright, and accordingly it is not clear whether the delay observed for other-race faces and the delay due to inversion are caused by the same or distinct underlying processes. If the presentation of upright other-race faces and inverted own-race faces disrupt the same mechanisms of structural encoding (i.e., configural and/or holistic processes), then the N170 face inversion effect should be decreased or absent for other-race faces. Alternatively, however, the effect of face inversion may be independent from, and additive to, the effect of face ethnicity. Under this prediction, a comparable inversion effect, e.g., on N170 latencies, shifted in time by the amount of the face ethnicity effect, would be expected.

The present study aimed at deciding between these alternatives by analyzing N170 components elicited by the presentation of same-race, other-race, and other-species (i.e., ape) faces in upright and inverted orientation. Additionally, pictures of house fronts were included as a non-face control condition. The stimulus classes used in the present study may therefore be seen as representing stepwise increasing deviations from the origin of our Caucasian participants' face space (Valentine and Endo, 1992), with other-race Asian faces as an intermediate stimulus class of comparably small deviance.

2. Materials and methods

2.1. Participants

Twenty Caucasian undergraduate students from the University of Jena (16 female) with a mean age of 21.5 years (±2.2 S.D.) participated in the study. Participants either received course credits or were paid 5€ per hour. All participants were right-handed according to a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971), and reported normal or corrected-to-normal vision. All participants gave written informed consent.

2.2. Stimuli

Stimuli consisted of photographs of unfamiliar Caucasian (same-race) or Asian (other-race) human faces, ape faces (great apes only), or house fronts (for examples, see Fig. 1). The majority of the human face stimuli were taken from the CAL/PAL database (Minear and Park, 2004). Pictures were edited using Adobe Photoshop™ to remove the background, and converted to gray-scale with black background. All stimuli were framed within an area of 170 × 216 pixels (6.0 cm × 7.6 cm), corresponding to a visual angle of 3.8° × 4.8° at a viewing distance of 90 cm. Finally, inverted versions of all images were produced by rotating the picture by

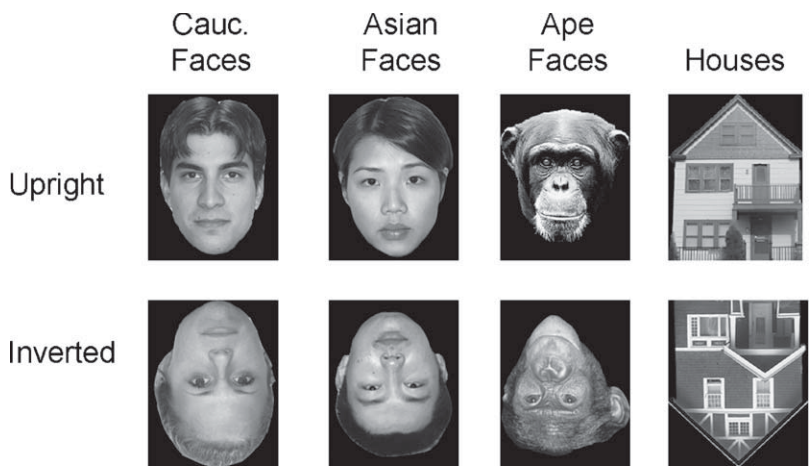

Fig. 1. Sample stimuli used in the experiment.

Table 1
Means and standard errors for reaction times (RT), as well as for N170 latency (in milliseconds, ms) and amplitude (in micro-Volt) measures at electrodes P9 and P10.

	Caucasian faces		Asian faces		Ape faces		Houses	
	M	SE_M	*M*	SE_M	*M*	SE_M	*M*	SE_M
RT (ms)								
Upright	491.25	14.3	489.27	13.69	531.21	11.49	535.02	14.14
Inverted	525.61	13.17	520.95	11.77	533.30	14.54	525.03	12.96
N170 amplitude								
P10 upright	−9.28	1.08	−9.10	1.05	−9.69	0.98	−4.59	0.95
P10 Inverted	−10.66	0.94	−11.06	1.13	−9.58	0.89	−4.58	0.95
P9 upright	−8.65	1.21	−8.52	1.07	−9.43	1.12	−3.88	0.66
P9 Inverted	−10.11	1.21	−10.44	1.22	−9.11	1.09	−3.75	0.81
N170 latency								
P10 upright	163.05	2.67	165.85	2.65	169.8	2.56	187.55	6.28
P10 Inverted	168.1	2.21	170.4	1.84	173.4	2.44	188.55	6.01
P9 upright	162.5	2.75	165.0	3.07	169.4	3.06	191.8	7.19
P9 Inverted	168.65	2.92	171.0	2.70	171.35	2.91	191.95	6.37

180°. 50 different exemplars of each stimulus category were used, and each image was presented two times, once in its upright and once in its inverted version, resulting in a total of 400 stimuli.

2.3. Procedure

Participants were seated in a dimly lit, electrically shielded, and sound-attenuated chamber (400-A-CT-Special, Industrial Acoustics, Niederkrüchten, Germany) with their heads in a chin rest. Each experimental session began with a series of 16 practice trials on different stimuli, which were excluded from data analysis.

Each trial started with the presentation of a fixation cross (500 ms), followed by a stimulus, which could be either the upright or inverted version of a Caucasian face, an Asian face, an ape face, or a house front (presented for 1000 ms). The trial ended with a blank screen presented for 1500 ms. Stimuli were presented in randomized order in five experimental blocks with self-timed breaks in-between. Ten stimuli from each of the eight experimental conditions (four stimulus types × two orientations) were presented per block. The task was to decide as fast and correctly as possible, via left and right index finger button presses, whether the presented stimuli were upright or inverted. Thus, the task did not include any social context, but merely focused on perceptual processes. Key assignment was counterbalanced across participants.

2.4. ERP recording and analysis

32-channel EEG was recorded throughout the experiment with a BioSemi Active II system (BioSemi, Amsterdam, Netherlands). The active sintered Ag/Ag–Cl-electrodes were mounted in an elastic cap. Recording sites corresponded to Fz, Cz, Pz, Iz, FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, F9, F10, FT9, FT10, TP9, TP10, P9, P10, PO9, PO10, I1, I2. EEG was recorded continuously with a 512-Hz sample rate from DC to 120 Hz. Please note that BioSemi systems work with a "zero-Ref" set-up with ground and reference electrodes replaced by a so-called CMS/DRL circuit (cf. http://www.biosemi.com/faq/cms&drl.htm for further information).

Contributions of blink artefacts were corrected using the algorithm implemented in BESA 5.1 (Berg and Scherg, 1994). EEG was segmented from −200 until 1000 ms relative to stimulus onset, with the first 200 ms as baseline. Only trials with correct responses entered the analysis. Trials contaminated by non-ocular artefacts and saccades were rejected from further analysis. Artefact rejection was carried out using the BESA 5.1 tool, with an amplitude threshold of 100 μV, as well as a gradient criterion rejecting all trials with more than 75 μV difference between two consecutive data points. Remaining trials were recalculated to average reference, digitally low-pass filtered at 40 Hz (12 db/oct, zero phase shift), and averaged according to experimental condition. A mean of 44.2 trials was averaged per condition, ranging from a minimum of 43.7 trials up to a maximum of 44.9 trials. An ANOVA on number of trials per condition with the factors 'stimulus type' and 'orientation' yielded no significant effects (all $F < 1$).

In the resulting waveforms, peak latencies for the N170 were determined at P9 and P10 between 130 and 200 ms. Since N170 peaks for houses were observed to occur substantially later in the grand mean waveforms, a different time window ranging from 160 to 240 ms was used for these stimuli. Individual peak amplitudes were determined for these components at the respective electrodes. Statistical analysis was performed by calculating repeated-measures ANOVAs, with degrees of freedom corrected according to Greenhouse-Geisser where appropriate. Significant main effects of stimulus type were followed-up by contrast analyses, comparing Caucasian (same-race) to Asian (other-race) faces, Asian (other-race) to ape (other-species) faces, and ape faces to houses. Significant interactions of stimulus type x orientation were further analysed by comparing upright versus inverted conditions for each stimulus class separately.

3. Results

3.1. Performance

Reaction times (RT, see Table 1) were analysed using a repeated-measures ANOVA with factors stimulus type (factor levels Caucasian faces, Asian faces, ape faces, houses) and orientation (upright, inverted). Significant main effects for both stimulus type ($F[3,57] = 43.9$; $p < .001$; $\eta_p^2 = .70$) and orientation ($F[1,19] = 19.4$; $p < .001$; $\eta_p^2 = .51$), as well as a significant interaction ($F[3,57] = 7.6$; $p < .001$; $\eta_p^2 = .29$) were detected. Post-hoc tests revealed that participants responded significantly faster to upright compared to inverted Caucasian ($F[1,19] = 15.1$; $p < .001$; $\eta_p^2 = .51$) and Asian faces ($F[1,19] = 28.5$; $p < .001$; $\eta_p^2 = .57$), but not to upright compared to inverted ape faces ($F < 1$) or houses ($F[1,19] = 1.4$; $p > .05$; $\eta_p^2 = .06$). In order to test whether RT differences occurred for Caucasian versus Asian faces, both upright and inverted stimuli of these stimulus classes were directly compared. RT did not differ, neither for upright ($T[19] = .49$, $p > .05$), nor for inverted faces ($T[19] = .83$, $p > .05$).

Accuracy was near ceiling (>.95 in all conditions). No statistical analysis is therefore reported.

3.2. ERP results

Since the present study explicitly focused on the early perceptual stages of face processing reflected in N170, we report detailed results from this component only.[1] ERPs demonstrated the expected occipitotemporal N170 component with maxima at P9/P10. In line with most previous studies cited in the Introduction, N170 was slightly larger over the right hemisphere. Scalp distribution in the N170 time range was very focussed and similar for all facial stimuli, with a more diffuse pattern for house stimuli (see Fig. 2). Table 1 depicts the latency and amplitude measures derived from the waveforms, which were used in the statistical analyses described below.

N170 latencies were observed to be delayed by inversion, but also in response to other-race, other-species, and non-facial

[1] In brief, analysis of P1 latency at electrodes O1 and O2 revealed a significant main effect of stimulus type ($F[3,57] = 22.7$; $p < .001$; $\eta^2 = .54$) due to significantly earlier peaks for house stimuli. Analysis of P2 amplitude at P9 and P10 revealed a significant stimulus type × orientation interaction ($F[3,57] = 5.0$; $p < .01$; $\eta^2 = .21$) due to larger P2 amplitudes for upright compared to inverted face stimuli which was not evident for houses.

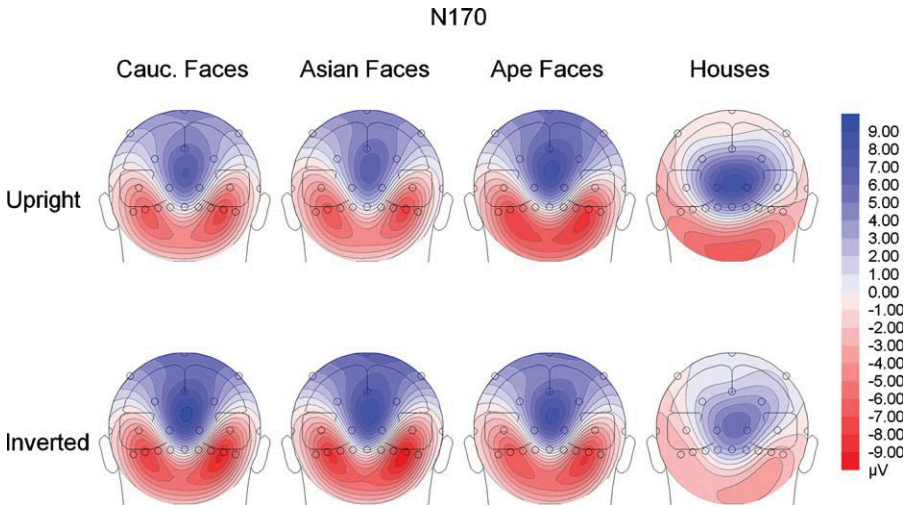

Fig. 2. Scalp topographical voltage maps (spherical spline interpolation, 90° equidistant projection) of the N170 peaks for the four stimulus classes. Negativity is plotted in red. Note the similar and slightly right lateralized occipito-temporal distribution for the different facial stimuli. µV = micro-Volt.

stimuli. Moreover, peak amplitudes were substantially enhanced for inverted Caucasian and Asian face stimuli (see Fig. 3).

A repeated-measures ANOVA on N170 latency (see upper part of Fig. 4) with the factors electrode (P9, P10), stimulus type (Caucasian faces, Asian faces, ape faces, houses) and orientation (upright, inverted) revealed significant main effects for both stimulus type ($F[3,57] = 14.0$; $p < .001$; $\varepsilon = .35$; $\eta_p^2 = .43$) and orientation ($F[1,19] = 22.6$; $p < .001$; $\eta_p^2 = .54$), as well as a significant interaction of stimulus type x orientation ($F[3,57] = 3.9$; $p < .05$; $\eta_p^2 = .17$). No effect of hemisphere was observed ($F < 1$). Contrast analyses on the factor stimulus type yielded significantly delayed N170 peaks for Asian compared to Caucasian faces ($F[1,19] = 25.9$; $p < .001$; $\eta_p^2 = .58$), for ape compared to Asian faces ($F[1,19] = 16.6$; $p < .001$; $\eta_p^2 = .47$), and for houses compared to ape faces ($F[1,19] = 10.5$; $p < .01$; $\eta_p^2 = .36$). Importantly, in an additional analysis restricted to face stimuli (Caucasian faces, Asian faces, ape faces) both main effects of stimulus type ($F[2,38] = 31.5$; $p < .001$; $\eta_p^2 = .62$) and orientation ($F[1,19] = 36.2$; $p < .001$; $\eta_p^2 = .66$) were found to be significant, but no significant interaction of stimulus type x orientation was observed ($F[2,38] = 2.6$; $p > .05$; $\eta_p^2 = .12$). Post-hoc tests comparing upright versus inverted orientation for the four different stimulus classes revealed significantly delayed N170 peaks for inverted compared to upright Caucasian ($F[1,19] = 30.4$; $p < .001$; $\eta_p^2 = .62$), Asian ($F[1,19] = 20.0$; $p < .001$; $\eta_p^2 = .51$), and ape faces ($F[1,19] = 6.6$; $p < .05$; $\eta_p^2 = .26$), but no significant difference for upright versus inverted house stimuli ($F < 1$). In order to test for the additive prediction of a comparable inversion effect for Caucasian and Asian faces, which is shifted in time by the amount of the face ethnicity effect, we additionally calculated the N170 latency inversion effect for both human face ethnicities (Cauc. Inverted–Cauc. Upright, Asian inverted–Asian upright). A repeated-measures ANOVA on the magnitude of the N170 latency inversion effect with the factors hemisphere (P9, P10) and stimulus

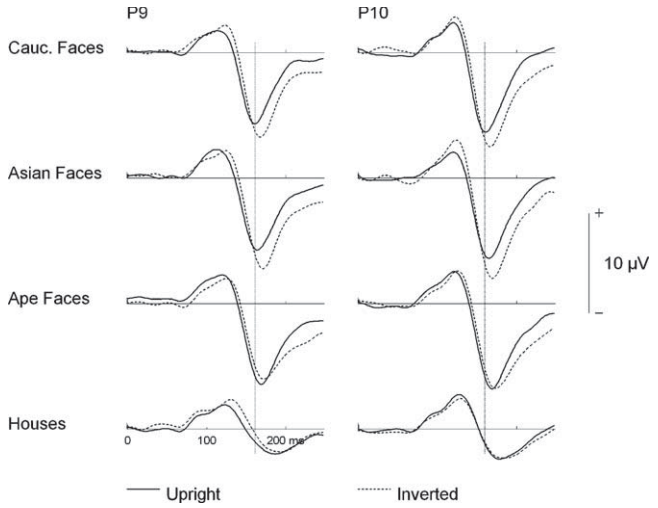

Fig. 3. Grand mean event-related potentials at electrodes P9 and P10 for upright and inverted stimuli. Note the gradually increasing N170 peak (dashed lines) for the different stimulus classes, and the additional effect of inversion for face stimuli. µV = micro-Volt, ms = milliseconds.

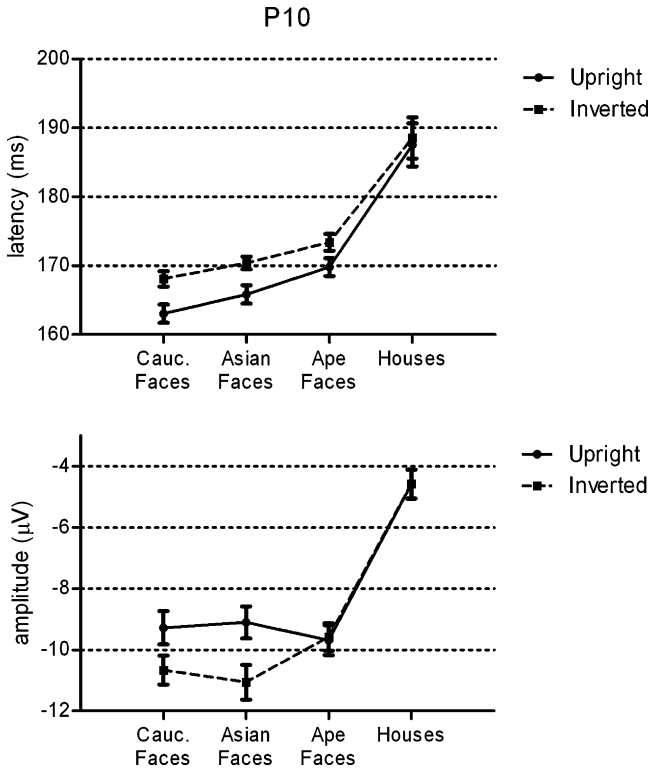

Fig. 4. Mean (± standard errors) N170 latency (upper part) and amplitude measures (lower part) at electrode P10. µV = micro-Volt, ms = milliseconds.

type (Asian faces, Caucasian faces) revealed no significant effects (all $F < 1$). This finding is in line with the hypothesis that the inversion effect on N170 latency is similar for Asian and Caucasian faces.

An analogous ANOVA on N170 peak amplitude (see lower part of Fig. 4) revealed significant main effects of stimulus type ($F[3,57] = 91.0$; $p < .001$; $\varepsilon = .56$; $\eta_p^2 = .83$) and orientation ($F[1,19] = 12.6$; $p < .01$; $\eta_p^2 = .40$), as well as a significant interaction of stimulus type x orientation ($F[3,57] = 9.6$; $p < .001$; $\eta_p^2 = .34$). No effect of hemisphere was observed ($F < 1$). The main effect of stimulus type was qualified by significantly larger N170 amplitudes for ape faces compared to houses ($F[1,19] = 141.6$; $p < .001$; $\eta_p^2 = .88$), but neither Caucasian and Asian faces ($F < 1$), nor Asian and ape faces ($F[1,19] = 1.2$; $p > .05$; $\eta_p^2 = .06$) differed significantly. Contrast analysis further revealed that the stimulus type x orientation interaction was neither significant for the comparisons of the factor levels Asian faces and Caucasian faces ($F[1,19] = 1.6$; $p > .05$; $\eta_p^2 = .08$), nor for ape faces and houses ($F < 1$). By contrast, a significant interaction for Asian faces versus ape faces was observed ($F[1,19] = 15.4$; $p < .001$; $\eta_p^2 = .45$). Post-hoc tests comparing upright versus inverted orientation for the four different stimulus classes revealed significantly enhanced N170 peaks for inverted compared to upright Caucasian ($F[1,19] = 12.1$; $p < .01$; $\eta_p^2 = .39$) and Asian faces ($F[1,19] = 19.4$; $p < .001$; $\eta_p^2 = .51$), but neither for ape faces nor houses (both $F < 1$; see Fig. 4).

4. Discussion

Although other-race faces have been reported to be processed less configurally and/or holistically, the present study is the first to systematically examine the effect of own-race and other-race face inversion on the N170, an ERP component which is known to be modulated by inversion, and is therefore sensitive to configural processing. We presented upright and inverted own-race, other-race, and other-species faces, as well as non-face object stimuli. In line with Itier et al. (2006), we found inversion effects in participants' reaction times for human face stimuli only. With regard to the electrophysiological findings, both other-race and other-species faces led to delayed N170 peaks. We therefore replicated our previous result with respect to N170 latency for own- and other-race faces (Stahl et al., 2008), although the effect was small in magnitude. Importantly, this effect of stimulus type was additive to the inversion effect on N170 latency, which was evident for all classes of facial stimuli. Finally, N170 amplitude was increased for inverted own- and other-race faces, but not for inverted other-species faces.

Both inversion and the presentation of other-race and other-species faces led to delayed peak latencies. Thus, our findings demonstrate a gradual temporal shift of the N170 peak with decreasing perceptual similarity of the stimuli to the faces of greatest expertise (i.e., own-race faces) for our participants. Importantly, the effects of stimulus type and orientation were additive and did not interact for face stimuli. It therefore appears plausible to assume that both inversion and the presentation of other-race faces delayed configural and/or holistic processing to a similar extent. Alternatively, inversion and the presentation of other-race/other-species faces could affect different processes, e.g., detection of first-order face-like configurations (delayed by face inversion) and holistic processing (delayed for other-race/other-species faces). Importantly, both explanations indicate that the processing of other-race and even other-species faces is not qualitatively different at the level of structural encoding, but that instead the same processes act less efficiently. Finally, it should be noted that, from the present data alone, an alternative explanation of slowed N170 responses to Asian faces, irrespective of the participants' ethnic group, cannot be fully excluded. More precisely, in principle it remains possible that structural encoding of Asian faces is per se more difficult, which may lead to the delayed N170. While on the basis of the own-race bias literature such an explanation based on differences in physiognomy between ethnic groups appears unlikely (see Meissner and Brigham, 2001), future studies examining participant groups from both ethnicities will hopefully clarify this issue.

Our findings on N170 latency are generally in line with previous studies. First, the presentation of ape or monkey faces has been observed to delay the N170 component relative to the presentation of human faces (de Haan et al., 2002; Carmel and Bentin, 2002; Itier et al., 2006). Second, significantly delayed N170 peaks for inverted ape faces (Itier et al., 2006; but see de Haan et al., 2002), but not for inverted non-face stimuli, such as houses (Rossion et al., 2000; but see Itier et al., 2006) have been observed before. Previous studies on the processing of other-race faces, however, either found no significant latency effects (Walker et al., 2008; Caldara et al., 2004; Herrmann et al., 2007), or reported a trend for (Caldara et al., 2003) or significantly shorter latencies for own-race faces (Stahl et al., 2008). Please note, that all studies that did not report a significant effect examined smaller populations, which may render the possibility to detect an effect of only a few milliseconds unlikely. In addition, although no latency measures are reported in the text, a closer look reveals at least hints for delayed N170 peaks in the ERPs as depicted in Caldara et al. (2004), Herrmann et al. (2007), and Walker et al. (2008).

All face stimuli elicited similar N170 amplitudes, which were larger than those for the house stimuli (for similar findings, see, e.g., Rossion et al., 2000; Itier et al., 2006; Eimer, 2000). However, whereas increased amplitudes for inverted Caucasian and Asian faces were observed, this effect was absent for the ape faces and house stimuli. This finding is again well in line with previous work that either found decreased (Itier et al., 2006) or equal N170 amplitudes for inverted compared to upright ape or monkey faces (de Haan et al., 2002).

Increased N170 amplitudes for inverted faces have been interpreted to result from the recruitment of additional analytic object processing resources (Rossion et al., 2000; Latinus and Taylor, 2006). Following this line of argument, these were probably not recruited for inverted ape faces in the present study, which may originate from the relatively large perceptual deviance to human faces. Alternatively, it has been suggested that the larger amplitude to inverted human faces is due to a recruitment of neurons responding to the eye region (Itier et al., 2006, 2007). According to this interpretation, inversion disrupts the configural processing of the face, which results in the disinhibition of eye-selective neurons in addition to face-selective neurons. Considering that humans are the only primates with white sclera, a selectivity of these eye-specific neurons to human faces is plausible. Thus, this line of argument would explain the similar or even smaller N170 amplitudes for inverted compared to upright ape faces found in previous and the present study. While it is not possible to decide between the two explanations from the present data, it appears important to note that the N170 amplitude effect of face inversion was similar for own- and other-race faces. Thus, the underlying mechanisms are similarly recruited for both stimulus classes. In combination with the latency results, we therefore suggest that the processes reflected by the N170 inversion effect are not qualitatively different, but temporally delayed, and thus less efficient, for other-race compared to same-race faces.

Some previous studies reported increased N170 amplitudes for upright other-race faces (Stahl et al., 2008; Herrmann et al., 2007; Walker et al., 2008) whereas others did not (Caldara et al., 2003, 2004). As we noted in our previous study, those studies that found an effect explicitly required the processing of the faces for identity. It thus appears that these task differences could explain

discrepancies in the literature on N170 amplitude effects for own- and other-race faces. Although the N170 is usually assumed to represent processes prior to face identification, a recent study found an N170-like component to distinguish between within- and cross-identity morphs (Jacques and Rossion, 2006), which was interpreted as reflecting the capture of those facial aspects essential for the discrimination of a specific stimulus from other faces during structural encoding. In line with this interpretation, the M170, an MEG equivalent of the N170, has been observed to differentiate between personally familiar and unfamiliar faces (Kloth et al., 2006). These studies suggest processes of face individualization in the N170 time range, which may differ for own- and other-race faces depending on task-demands.

In sum, with respect to recent findings of less configural and/or holistic processing of own-race compared to other-race faces (Michel et al., 2006a,b; Tanaka et al., 2004; Hancock and Rhodes, 2008; Hayward et al., 2008; Murray et al., 2003), the present study adds important new results. Both holistic and configural processes are assumed to be severely disrupted by inversion (see e.g., Maurer et al., 2002). Thus, a decreased N170 face inversion effect for other-race faces may have been expected, and, given our previous result (Stahl et al., 2008) of delayed N170 latencies for *upright* other-race compared to own-race faces, no (or little) additional delay for *inverted* other-race faces may have been hypothesized. By contrast, the present study not only replicated the previously described delayed N170 peak for other-race faces, but also demonstrated highly comparable inversion effects for both own- and other-race faces. This suggests that structural encoding is not qualitatively different, but is delayed and therefore less efficient for other-race compared to own-race faces. This less efficient processing of other-race faces may underlie many of the phenomena observed in behavioural studies.

It is important to note though, that the present experiment did not involve recognition of individual faces. Although the structural encoding processes reflected in the N170 are a necessary prerequisite for face identification, later ERP components are more likely to account for ethnicity effects on the recognition of an individual face (Stahl et al., 2008). Accordingly, it remains to be determined to what extent delayed structural encoding mechanisms reflected in the N170 contribute to the own-race memory bias. Recently a similar own-age memory bias (young participants were found to be more accurate at recognizing young compared to old face stimuli) has been observed in the absence of an N170 delay for old faces (Wiese et al., 2008). The study of similarities and differences between own-race and own-age biases can be expected to provide further insights into the mechanisms underlying these phenomena, both at the perceptual and memory level.

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Eidesstattliche Erklärung

Ich erkläre hiermit, dass mir die geltende Promotionsordnung der Fakultät für Sozial- und Verhaltenswissenschaften der Friedrich-Schiller-Universität Jena bekannt ist.

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